INTERNATIONAL GEOSPHERE/BIOSPHERE PROGRAM 1984

HEARINGS

BEFORE THE

SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS

OF THE

COMMITTEE ON SCIENCE AND TECHNOLOGY U.S. HOUSE OF REPRESENTATIVES

NINETY-EIGHTH CONGRESS

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INTERNATIONAL GEOSPHERE/BIOSPHERE PROGRAM: 1984

WEDNESDAY, SEPTEMBER 12, 1984

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS,
Washington, DC.

The Subcommittee met, pursuant to call, at 1:30 p.m., in room 2318, Rayburn House Office Building, the Honorable Harold L. Volkmer (chairman of the subcommittee) presiding.

Mr. VOLKMER. The Subcommittee on Space Science and Applications will come to order.

Today we open 2 days of hearings on the International Geosphere/Biosphere Program. Just over 25 years ago, the International Geophysical Year opened the space age with the launch of Sputnik and also demonstrated that a coordinated, interdisciplinary study of the Earth could yield valuable results.

These two activities—the Space Program and the study of the Earth—have remained linked together because in situ and remote sensing by satellites can contribute so much to Earth science. Indeed, advances in satellite technology, coupled with advances in our ability to handle quantities of data, make it feasible to consider an ambitious program such as the IGBP.

We are led to consider a program such as International Geosphere/Biosphere Program for two basic but different reasons. Both are equally important on different time scales. First, we have on our national and international agendas right now several problems that demand global, interdisciplinary scientific work for their solution. Among these I would include acid rain, the CO_2 greenhouse effect, deforestation, nuclear winter, and the ozone-freon interaction. In other words, these are problems we see now.

The second reason for International Geosphere/Biosphere Program is simply to understand the world we live in. I believe this reason drives many members of the scientific community. However, I want to say to my colleagues in Congress that while such understanding may not have an identifiable application now, it will surely help us avoid, or recognize sooner, tomorrow's problems.

I must acknowledge that this program cuts across many jurisdictions. Our subcommittee has taken the lead because of the prominence of space technology in global scale Earth science research programs, but I want to make it clear that virtually every subcommittee of this committee will have an interest in the International Geosphere/Biosphere Program.

Let me turn now to today's witnesses, who will appear together as a panel:

Dr. Thomas Malone is scholar in residence at St. Joseph College in Connecticut; natural sciences fellow at Resources for the Future; and perhaps more importantly for our purposes, a convenor of the Symposium on Global Change of the Ottawa Meeting of the International Council of Scientific Unions on September 25. That symposium is the first step toward realization of International Geosphere/Biosphere Program as a working program. Dr. Malone will be able to illuminate for us the special international aspects of the International Geosphere/Biosphere Program.

Our second witness, Dr. Francis Bretherton, is an oceanographer at the National Center for Atmospheric Research in Boulder, CO, and chairman of NASA's Earth System Sciences Advisory Committee. Dr. Bretherton can describe how NASA can fit into the International Geosphere/Biosphere Program concept and also how the larger scientific community is likely to react to International Geosphere/Biosphere Program and to NASA's involvement.

Gentlemen, I first wish to thank you both for being here. Your statements will be made a part of the record in full and you may either review your statements in full or you may summarize, however you so desire, and we will begin with Dr. Malone.

STATEMENTS OF DR. THOMAS F. MALONE, SCHOLAR IN RESIDENCE, ST JOSEPH COLLEGE AND COCONVENOR, SYMPOSIUM ON GLOBAL CHANGE, INTERNATIONAL COUNCIL OF SCIENTIFIC UNIONS, OTTAWA, CANADA; AND DR. FRANCIS P. BRETHERTON, SENIOR SCIENTIST, NATIONAL CENTER FOR ATMOSPHERIC RESEARCH AND CHAIRMAN, EARTH SYSTEM SCIENCES ADVISORY COMMITTEE, NASA

Dr. MALONE. Thank you, Mr. Chairman. We very much welcome your interest in this endeavor. I will try to respond to the several issues to which you invited my attention in your letter.

As a sort of preferatory note, may I simply give the five reasons I think that it is timely, why an IGBP now? Progress in the atmosphere, the oceans, the solid Earth, solar terrestial domain, in the life within the biosphere, has moved ahead, but just as we have come to realize in very emphatic fashion that the atmosphere and oceans are so closely linked, that the programs are almost common now, we are recognizing our links and it is my judgment that progress in each of these five fields will plateau unless we look at the system as a whole. So that is one reason.

The second reason is that there are actually attractive scientific problems that lie out there ahead of us and they are in the process of being identified.

Third, we have the technology available to address these issues in the manner that has been under consideration at the present time. We have a global observational capability from satellites, and we have the exquisiteness in instrumentation to measure parts per billion, and the computers to run analytical studies and to handle the fantastic quantities of data which would be generated by a program of this kind.

A fourth reason is the emergence of anthropogenic changes. You mentioned some of those specifics. I am always very taken by the sagacious words of Richard Goody in one of his habitability papers and I think something everyone should be aware of. He wrote "the human race lives on a planet characterized by change." He went on to say, "this is a unique time, which one species—humanity—has developed the ability to alter its environment on the largest, that is, global scale, and to do so within the lifetime of a single species member. Changes that may affect the ability of the planet to support communities of plants and animals." And he went on finally, "However, humanity has the ability to manage its resources, to plan intelligently for its future." I think that is a very powerful argument.

A fifth and final reason is that we are clearly moving into an era when the increase in population and the growth in demands on the goods and services obtained from the natural resources, particularly in the developing countries, is going to be great. So we must have the knowledge base to manage this environment intelligently in the fashion that Dr. Goody pointed out.

I would like, in addition to saying that this is important, I would like to point out the difficulties in mounting an effort of this kind. The difficulties are two kinds. It is the difficulty of getting an international program going. It is always easier to develop a national program than it is to get the whole international community involved. That is one problem. I am sanguine about that. I have been to Beijing, I have been to Moscow.

The meeting you mentioned draws from all over the world in Ottawa and the alacrity with which people have responded, and particularly the interest that I did find in both Beijing and Moscow, and yesterday I received a letter from the Institute of Geography in the Academy in Moscow, expressing very keen interest in this program. So I am persuaded that the difficulties can be overcome and a successful international program can be mounted.

The other kind of difficulty is the fact that this program inherently will be multidisciplinary, and scientists by tradition are quite comfortable working in a discipline, pursuing a rather restricted set of problems. You can't find someone who knows enough about all of these fields, you have got to get specialists working together. That is not easy. It flies in the face of the reward system and the scientific tradition.

In addition to the scientific reluctance, the reluctance of scientists—institutions which support these programs have their own ways of doing things—and they are comfortable in pursuing the way they have traditionally pursued them, and so that both the way of thinking of scientists and the way of thinking of institutions is going to have to be altered in order to respond.

Now, you asked about the philosophy. I think it is well spelled out, first of all, by George Garland, at the General Assembly of the International Council of Scientific Unions in 1982 when a commemorative lecture on the International Geophysical Year, he said:

> Today we have a reasonably complete understanding of the links between physical processes affecting our planet and the region around it. Many of the mysteries which remain involve the interaction between these physical processes and biological material, including man himself.

I think one of the real important things in the International Geosphere/Biosphere Program is the linking of the biological side and the physical side.

Herb Friedman, who is chairman of the Commission on Physical Sciences, Mathematics, and Natural Resources of the National Research Council, in the preface to a report on a workshop of the Council wrote:

> The real connections that link the geosphere and biosphere to each other are subtle, complex and often synergistic; their study transcends the bounds of specialized, scientific disciplines and the scope of limited, national scientific endeavors. For these reasons, progress in fundamental areas of oscen-atmosphere interactions, bio/geochemical cycles, and solar-terrestrial relationships has come far more slowly than in specialized fields, in spite of the obvious practical importance of such studies. If, however, we could launch a cooperative interdisciplinary program in the earth sciences, on an international scale, we might hope to take a major step toward revealing the physical, chemical and biological workings of the Sun-Earth system and the mysteries of the origins and survival of the life in the biosphere.

I think this is a very eloquent statement and I know Dr. Bretherton will share with us his thinking on it.

Now, the goal is really to understand the natural processes in the Sun-Earth system which govern changes, so that we can anticipate natural changes anthropogenic changes. The specific objectives to pursue within that broad goal, for example, an understanding of the bio/geochemical cycling link, flow of nutriments of carbon, nitrogen, phospherous, sulphur, and water, which sustain the ecosystems, that underwrite life on the planet.

These are in a state where illumination of these cycles is essential and they constitute the linkage or the glue that hold together the biological aspects and the physical aspects.

Now, the idea, as I said, began I think with George Garland's talk. The Executive Board met in January, 6 months after that, and pondered the question. A meeting was held in Warsaw of the General Committee in August of 1983, and we were urged to set up the symposium which you referred to, and now there are approximately two dozen scientists from 14 different countries who will gather in Ottawa on September 25 in front of an audience of about 300 interested scientists who have in their hands the preprinted submissions of these authors, and there will be an intensive exercise all day long of discussion between the authors and the 300 scientists.

We have had this planned very tightly. It is a very tight schedule. Out of this I hope will come several themes which will be pursued by intensive workshops involving the 20 scientific unions and the 71 national hearing bodies, over the next 2 years. So that by the next General Assembly—that is September 1986—I think it is more than a dream to believe that a persuasive, coherent program will be in hand, which will enlist the enthusiastic support of scientists and the involvement of the national governments.

Why international? All you have to do is look at the El Nĩno phenomena to realize that an event in one part of the world will have profound thrust on another part of the world. Why can't we do this from satellites? Simply because we need to have ground truth and not all of the processes we wish to study can be studied from satellites. Moreover, participation in illumination or establishing this knowledge base is important if the output of that is to

be used in managing the environment. So we do need to involve all the nations of the world.

What can other nations contribute? Two things: Intellectual contributions and material contributions. I am persuaded from reading the 25 papers at Ottawa that the intellectual contribution is important. Probably the world's greatest expert on biochemical cycles is in Sweden. The word's best expert on sulphur cycling is in Russia. You find this all over the world, and there is no point in our trying to do everything when other nations are prepared to participate and with two-thirds of the world scientists outside the borders of the United States, I think we have everything to gain and nothing to lose in building on the magnificent record of the IGY.

I hope your committee will keep a close eye on this and as it develops, and it reaches a stage where you feel action by Congress would be helpful—I would suggest from my experience that a concurrent resolution of the two Houses would be a superb action on the part of the legislative branch in promoting this at the time that you have before you a more persuasive specific case than I have tried to present.

Thank you, Mr. Chairman.

[The prepared statement of Dr. Malone follows:]

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TESTIMONY OF DR. THOMAS F. MALONE, NATURAL SCIENCES FELLOW, RESOURCES FOR THE FUTURE, WASHINGTON, D.C. AND CO-CONVENOR, SYMPOSIUM ON GLOBAL CHANGE, INTERNATIONAL COUNCIL OF SCIENTIFIC UNIONS, OTTAWA, CANADA

Mr. Chairman:

The interest of your subcommittee in the process of exploring a strategy for a multi-disciplinary, international program that would take a comprehensive look at Sun-Earth interactions is most heartening. The task is both important and exceedingly difficult. Important, because if the planning is completed successfully, it will lead to a program that would provide the knowledge base for the management of the global life-support system which must meet the increasing demands of a growing population during the 21st century. Moreover, if such a program were to be successfully executed, it would make a contribution toward building bridges of understanding among nations that sorely need those bridges in an increasingly interdependent yet contentious world. Difficult, because scientists feel most comfortable in the pursuit of knowledge along disciplinary lines and the tradition of reductionism makes collaborative efforts among disciplines difficult to achieve.

You have asked me to address seven issues from an international perspective:

- Philosophy
- Goals and objectives
- Present status
- Why international?
- Why not address global aspects through satellites?
- What contributions can we expect from other countries?
- How best to proceed internationally?

The underlying philosophy of this proposal was succinctly set forth, first, by Professor George Garland (Past President of the International Union of Geodesy and Geophysics) in a lecture commemorating the 25th anniversary of the International Geophysical Year during the 1982 General Assembly of the International Council of Scientific Unions (ICSU) in Cambridge, England. He remarked:

> "Today we have a reasonably complete understanding of the links between physical processes affecting our planet and the region around it. Many of the mysteries which remain involve the interaction between these physical processes and biological material, including man himself."

This concept was developed further by Dr. Herbert Friedman, Chairman of the Commission on Physical Sciences, Mathematics, and Natural Resources of the National Research Council in the preface to a report on a workshop of the Council when he wrote:

> "The real connections that link the geosphere and biosphere to each other are subtle, complex, and often synergistic; their study transcends the bounds of specialized, scientific disciplines and the scope of limited, national scientific endeavors. For these reasons progress in fundamental areas of ocean-atmosphere interactions, biogeochemical cycles, and

solar-terrestrial relationships has come far more slowly than in specialized fields, in spite of the obvious practical importance of such studies. If, however, we could launch a cooperative interdisciplinary program in the earth sciences, on an international scale, we might hope to take a major step toward revealing the physical, chemical, and biological workings of the Sun-Earth system and the mysteries of the origins and survival of life in the biosphere.

The goal of the program we are exploring now is to develop an understanding of the natural processes in the Sun-Earth system which govern changes in that system in order that we may be able to anticipate with reasonable assurance changes that will occur in the system. Not only must we be able to understand natural changes, but we must also seek to understand the influence of human activity on that system (i.e., anthropogenic changes). The sagacious words of Professor Richard Goody and his colleagues are relevant here:

"The human race lives on a planet characterized by change ---- This is a unique time which one species, humanity, has developed the ability to alter its environment on the largest (i.e., global) scale and to do so within the lifetime of a single species member ... changes that may affect ... the ability of the planet to support communities of plants and animals ... however, humanity has the ability to manage its resources to plan intelligently for its future ..."

Specific objectives must be formulated over the next two years to be pursued through a set of sharply focused scientific programs to be mounted during the 1990's.

The roots of this program go back to the 17 century when Francis Bacon urged "cooperative efforts" as the best way to obtain information about the nature of the world. The work of the Russian mineralogist V. I. Vernadsky in developing the notion of the "biosphere", stressing the inextricable linkage between life and its surrounding energetic and material through photosynthesis, transpiration and nutrition contributed to the intellectual framework. The series of Polar Years beginning a century ago and culminating inthe famous International Geophysical Year and its "daughter" programs established the pattern of international cooperation. Major impetus to the present activity, however, was provided by the views of Garland and Friedman summarized above. The idea of an international collaborative activity was considered by the Executive Board of ICSU in Stockholm in January, 1983. The decision to explore the feasibility of an international effort was made at a meeting of ICSU's General Committee in Warsaw in August, 1983. Over the last several months two dozen scientists from fourteen different countries have been preparing essays on this concept from their particular disciplinary point of view. These have been gathered together in preprint form and distributed to more than 300 scientists from all over the world who will gather in Ottawa, Canada, on September 25th at an ICSU Symposium on Global Change. This Symposium is intended to be the first step in a

two-year systematic exploration by ICSU and its constituent bodies of the desirability of actually launching a program currently embraced by the IGBP. The conclusions and recommendations of the Symposium will be presented to the General Assembly of ICSU in Ottawa. A decision will then be made whether or not to pursue the development of a scientific strategy during the next two years. This is likely to take the form of a half dozen workshops addressing themes that are likely to emerge from the Global Change Symposium. Participation in these workshops will be drawn from the membership of the 20 Scientific Unions covering all the disciplines of science, and the 71 National Academies or analagous bodies that constitute ICSU. Since the global observational potential of remote sensing will surely play an important role in any program that may eventually emerge, the involvement of a consortium of national space agencies would be quite appropriate. Similarly, as the scientific directions take shape it will be desirable to maintain close interaction with the intergovernmental agencies which bring together the collective strengths of national governments throughout the world. By the time of the next General Assembly of ICSU (in 1986) it may be expected that a coherent and persuasive program could be presented to the world scientific community with some assurance that national governments will look with favor upon implementing the strategy fashioned in this manner. So much for the present status.

With respect to the question "Why International?", we know that the processes linking the atmosphere, ocean, Earth, plant and animal life, and the solar energy from the sun that drives the system, have proceeded for millions of years oblivious to national boundries. Events in one part of the world (e.g., El Nino)have profound effects over substantial portions of the Earth at great distances from the event itself. Moreover, the impact of human activity on the global life-support system has now reached global dimensions (e.g., potential climatic impact of the injection of carbon dioxide into the atmosphere from the combustion of fossil fuels or the acid deposition at points far removed from the source of the sulfur dioxide). The basic philosophy of the proposed program sketched above, and the nature of the system which this program would attempt to understand, dictate that the effort be international.

Since it is manifestly more simple to mount a national program than it is to fashion an international collaborative effort, it would be tempting to explore the possibility of using satellites to meet the requirement that the program be global in scope. Promising as is the potential for remote sensing to contribute substantially to the proposed program, the observational needs to illuminate complex processes such as the biogeochemical cycling of nitrogen, carbon, sulfur, phosphorus and water vapor that play such an important role in linking together the ocean, atmosphere, Earth and biota (as well as being essential to nourish all forms of life) make necessary in situ observations. Moreover, even the best remote-sensed observations require "ground truth" for validation. Finally, if the knowledge gained through such an endeavor is to find practical utility in the management of the biosphere during the next century, it is essential that participation in the acquisition of that knowledge base involve all nations who will be concerned with putting in place policies for managing the biosphere.

The experience of the past hundred years suggest two kinds of contributions from other countries in an endeavor of this kind: intellectual and material. A quick perusal of the preprint volume prepared for the ICSU Symposium on Global Change in Ottawa by scientists from fourteen countries is persuasive evidence that there is a rich potential outside the United States for intellectual contribution to the IGBP. Moreover, the tradition of sharing of data and cost-effective observational and data-management systems almost dictate a collaborative effort. With two-thirds of the world scientists resident beyond the boundaries of the United States it is evident that a collaborative effort not only is desirable but is necessary. The experience in the IGY and the several programs which followed from it present a persuasive case from the importance of contributions -- both intellectual and material -- from other countries.

The role of Congress in an international program? From the background of a privileged observer and occasional participant in the evolution of the Global Atmospheric Research Program from a single sentence in President Kennedy's address to the United Nations in 1961, through the tortuous path that led to endorsement by the world scientific community in 1967 and concurrence by a special assembly of governments in 1968, to the actual implementation of the 1967 strategy during the first GARP Global Experiment in 1978-79, I would urge a blend of patience and constant interaction with the process on the part of Congress as the program unfolds. Your Subcommittee can play an important role in making sure that this program is <u>not</u> simply a "bundle" of international activites that the scientific strategy is sound and realistic, that the infrastructure of diverse scientific activity within nations -- in particular our own -- supports and enriches large international activities, that large observational programs have specific scientific objectives and that there be a balance between expenditures in support of these observational programs and support for the research that makes use of observational data collected, that the explosively developing potential for data management be effectively deployed in providing the data banks upon which research will depend, that the scientific infrastructure in the developing nations be strengthened so that the knowledge gained during a sustained international endeavor can be effectively deployed in the management of the life-support systems in those nations where stresses are expected to be particularly severe during the next century.

At that moment in time when you are satisfied that the planning is sound, and the execution feasible, a concurrent resolution would be of enormous value.

Meanwhile, I hope your Subcommittee will continue to play the role of a "critical lover", not that of an "unloving critic" nor an "uncritical lover", to borrow from the words of John Gardner.

Mr. VOLKMER. Thank you very much, Dr. Malone.

Dr. Bretherton.

Mr. BRETHERTON. Yes, sir.

My prepared statement is being distributed. One of the comments I got from my colleagues, it was too long to read it, so I am going to have to summarize it, and as an aid to doing that, I have prepared a vugraph which if you will welcome, I will just display.

Mr. VOLKMER. Yes.

Mr. BRETHERTON. As you see, this is really more than an outline of my remarks. Let me first of all say that I wholeheartedly agree with the philosophy and indeed the substance of the case that Dr. Malone has just presented. I just won't take your time going over that part of it again.

We are talking about a program to better understand the Earth, how it really functions as a complete system. That means not artificially prescribing ourselves by traditional disciplinary patterns of thoughts, institutional patterns of thoughts or national patterns of thought. And the exercise we are engaged in is very much one of how do we break out of those bounds, because the problems we are dealing with absolutely require us to do so.

I come as chairman of the Earth Systems Sciences Committee, as you have already mentioned. This is a committee reporting to the NASA Advisory Council, charged with looking at all of NASA's Earth looking programs, and coming up with an implementation strategy for how to achieve the scientific objectives that Dr. Malone has so eloquently described.

In the course of doing that, we have to grapple with a number of very substantial problems, like what should NASA's role be in such a program versus the role of other agencies? And what I am presenting here is sort of the result of the first 6 months of deliberations of this committee. We are not expecting to have our full report ready for another 18 months or so, but we have come to some sort of a consensus as to our present ideas, at least of the framework within which we are proceeding, and that is what I am describing to you here and we are talking about that the strong U.S. national effort as an absolutely essential tool toward implementing what Dr. Malone has been describing as a truly international program. Unless within the United States we can get our act together first, the international efforts will be very, very much harder, and heaven knows, they are hard enough as it is.

The second point is that the core of that national program will probably almost certainly, in fact has to be focused around three agencies—NASA, NOAA, and NSF. We have a very strong interaction working out from that toward a very large number of other agencies that are involved. The structuring of this is rather deliberate, recognizing the difficulty of getting simultaneous action among all the interested bodies concerned, that we have to narrow the focuses as a core of the program down to the three agencies concerned.

Now, the ideas we are talking about are very strongly related to things that have previously been described as Global Habitability or the proposed International Geosphere/Biosphere Program. I would remark that although there is very strong overlap, they have arisen for related but somewhat different reasons, and as a

result, you will find in the deliberations of our committee a somewhat different emphasis in detail from those that have been found in previously Global Habitability and are also being found in the deliberations of the Academy Committee.

My view position is that those differences are minor at this stage and they are more concerned with the history and the background of the group that happens to be doing the discussing rather than the real substantive pieces of the program. But this is an issue that we can come back to and discuss in more detail, if you wish, later.

Finally, I would like to draw your attention to where we see where some of the real difficulties are in actually implementing the vision that we have in front of us. I say this as a working scientist, who is strongly influenced by that vision but, nevertheless, has spent quite a lot of time thinking about how does one get this actually to happen, and we have a number of problems which are tough.

We start with the fact that the real value of a program of this sort comes when you are able to look at the sort of changes in the system and how the system functions in the long term. What I mean by that is at least over one to two decades. There is no quick answers here and in particular, we are having to follow changes in the system and its reponse to the many pressures which are on it, both natural and anthropogenic, and unless we are able to sustain things in that long haul, much of the value of the program will disappear.

The test I put on that is if we are making a major program of observations now globally, how will it look in 20 years time to our successors when they look back and say are the changes that have taken place or seemed to have taken place in those 20 years, are they real, do we have an adequate record of what happened? That will be the acid test of whether our program is well based.

Another problem issue, which is clearly arising, is the relationship between this program and space stations. This would appear to be an internal NASA matter, but as you are probably aware, there is a strong case being made from many places—I happen to agree with that case—that we have to be thinking here of an integrated Earth observing system which looks at the operational or near term applications of the satellite systems as well as the longer term scientific ones I am talking about, and we have to build that synergism and apply this to questions like what really are the uses of space stations, both manned space elements and the unmanned platforms that are being described.

We have already talked about the international framework into which a program of this sort has to be imbedded and I agree completely with Dr. Malone on that, the reasons are only partially those of saving money or saving resources. The real overwhelming reason is that if humankind as a whole is to be better equipped to face the shorter term problems that they are going to be wrestling with and are wrestling with now concerning our environment, if they are to be better equipped to do that, it is essential that key individuals spread through all the nations of the world be involved in the acquisition of that knowledge base and understanding, otherwise experience shows that it will be almost largely wasted.

I have already mentioned, too, the problems associated with interagency coordination. The Earth System Science Committee, although it has no formal charge in this area, is acting as if it were a spokesman for a national effort in this area, and is working as hard as it can behind the scenes to make sure that the relevant issues are discussed and understood through the regular agency channels. As you will well appreciate, we are bold indeed to take on this one. Nevertheless, it is, in our view, the essence of the problem and if we shied away from that, we would simply not be doing our job.

Finally, as you mentioned informally just before these discussions, there is one common theme that always comes up here, the resources required. I am not able at this point to tell you what a meaningful program in this area would actually cost. This is a very complicated issue because in many things we are not talking about new resources. We have most of the observation systems we are talking about in place already. It is a question of pointing and of supplementing them in ways that will really make them useful for the sorts of problems that we are now trying to address. And I am not saying that new systems are not required. They will be, but it is certainly not trying to design a whole program starting from the ground up. We are trying to build upon and influence a great deal of activity worldwide, which is going on already.

For example, one of our major sources of knowledge about the existing complement comes from the analysis daily prepared by the weather services of the world. Can we make them more useful for our purposes? This is one of the questions that comes up repeatedly in the course of our deliberations.

To summarize, I am representing a group which is trying to build a consensus within both the scientific community and in the relevant agencies toward a strong U.S. national effort in this area, and we would appreciate indeed any guidance or comments that you would care to give us in the course of our activities.

Mr. VOLKMER. Thank you very much, Dr. Bretherton.

[The prepared statement of Dr. Bretherton follows:]

The House Committee on Science and Technology
Hearings on

The International Geosphere Biosphere Program

A Statement by

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The Central Theme

I am here as an advocate of:

A strategy to better understand the planet Earth using a program of global observations

including a strong U.S. initiative embedded in an international effort. The primary U.S. agencies would be NASA and NOAA, with NSF in a key supporting role. Collaboration is expected with DOD, DOE, DOI, DOS, DOT, EPA and USDA. The theme is the earth as a functional system, emphasizing primarily the fundamental understanding which must underlie intelligent handling of the many environmental issues which have arisen in recent years and will continue to arise, rather than specific issues themselves. At the same time, the expectation remains that in due course this fundamental understanding is likely to contribute to these more immediate concerns, and an effective implementation strategy has to address the scientific program in the context of the totality of what needs to be done and is likely to happen for other reasons, both immediately and in the longer term.

Background

I speak as a private individual, drawing on my experience as a scientist mainly in the fields of meteorology and oceanography, as former Director of the National Center for Atmospheric Research, as a participant in the national and international planning activities of the World Climate Research Programme (WCRP), and particularly as Chairman of the Earth System Sciences Committee (ESSC) of the NASA Advisory Council. I have not personally been closely involved in preparation of present plans for the International Geosphere Biosphere Program (IGBP). My bias is towards the issues related to large scale observation systems, particularly from satellites. Many of my concerns are not scientific in nature, but rather institutional and managerial. This is because, though science is central to achieving the basic objectives and fascinating in its own right, the still incomplete clarification of the scientific strategy has progressed relatively further than consideration of how it may realistically be implemented.

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The activity referred to here has considerable overlap with the previously advanced concept of Global Habitability, the existing World Climate Research Program, the proposed IGBP and many other efforts originating within diverse groups. This variety of labels illustrates the widespread concern among scientists and others over the global environment of humankind, and the complexity of the task of better understanding it. In addition, since every group starts from a different set of assumptions about just what are the most significant aspects of the system and about just what actions are realistic in addressing them, there are inevitably at this stage divergences of definition and emphasis within a broad degree of consensus about fundamentals. In particular, within similar overall program concepts different advocates assign different weights to different subsystems, such as biogeochemical cycles, the solid earth or solar terrestrial linkages. Further close examination is needed to reveal which subsystems are more closely linked than others and on what timescales, and to what extent observational and analytical approaches for each are complementary and mutually supportive and to what extent they are competing for scarce resources. What is important now is the framework within which such examination and initial actions can best proceed. Decisions on detailed priorities will ultimately have to be made, but it is critical that the issues be first examined broadly enough in ways which are relatively unconstrained by traditional institutional or disciplinary boundaries.

Program Rationale

The rationale for such a program is as follows:

The land, ocean, atmosphere and biota form an interactive system that functions on a global scale. In the past, the earth sciences have tended to treat these components as separate disciplines, and much is known, for example, about the processes which govern the winds and temperature in the atmosphere, or about the chemistry of trace substances in the ocean. In the last few decades, however, increasing attention has become focused on questions that transcend traditional disciplinary boundaries, and require, in addition, an understanding of the complex linkages and feedbacks between these components. The climate changes to be expected from the worldwide consumption of fossil fuels, the sensitivity of the stratospheric ozone to trace gases such as fluorocarbons, the causes of past extinctions of whole classes of living species--these are questions of fundamental importance that can only be addressed from a global, interdisciplinary perspective, drawing on a wide range of observations and skills quite beyond the range of any one individual or institution.

Observing and understanding such a complex system is a basic intellectual challenge. Yet these questions and others like them are issues that must be resolved if we are to predict the future or even diagnose correctly the changes which are underway around us, some the results of activities of humankind, others natural fluctuations for which the precedents are undocumented or simply unrecognized. The planet Earth is our environment, and, for better or for worse, we are part of that environment, reacting to it and acting on it, both in ways that are far reaching but as yet barely perceived. It behooves us to pay attention.

Obtaining such understanding requires a long term study both of the individual parts of the system and the interactions between those parts. This implies building an information base including sustained global observations, and evolving quantitative models to be used for examining responses and feedbacks as well as predicting the behavior of the whole. The required information base is large and diverse. Some pieces, such as long records of surface temperature at land stations in northern temperate latitudes, already exist, though not necessarily in a form that is readily accessible. For others, modifications of existing operational data sources are appropriate. For yet others, particularly those providing global coverage, the deployment of new observational systems will be required. The coverage and uniform data quality obtainable implies a critical role for satellite based remote sensing, but extensive in situ measurements are also needed, distributed in key locations around the globe. In a few instances, further development of instruments will be necessary. Finally, this observational program must be accompanied by a corresponding effort on data management, analysis and modeling. To be effective, an Earth Observational System must be conceived and evaluated as a whole, including contributions from other nations.

A proper international basis for such an enterprise is necessary for at least three reasons. For many of the essential variables, observations can only be made and data exchanged with the active collaboration of the nations within whose territory or economic zone they are required. These observations are often made primarily for other purposes and the cost of the U.S. duplicating the entire system would be prohibitive even if technically feasible. Finally, (and personally I find this reason the most compelling) the purpose for improved understanding of the system is to enable more intelligent actions on problems of global concern. Without active participation by both scientists and governments from around the world in the process of establishing that understanding, it is unlikely to influence their actions.

A major effort to achieve these objectives is timely now. As world population and economic aspirations press harder on finite resources, the need for improved understanding grows year by year, and problems such as acid rain, desertification and droughts become ever more prominent yet less amenable to easy solutions. Modern computer systems make it feasible to simulate quantitatively many of the features of the complex interactions between subsystems. Space based remote sensing and data transmission capabilities allow for the first time a global view. The international scientific community has recognized the critical importance of the objectives and has delineated strategies for working towards them, based on solid advances within the individual disciplines and on growing awareness of their interdependence. Though much remains to be done, the basic elements of a program are at hand. A commitment to the grand design is needed now. Without it these efforts will remain unfocused and will inevitably dissipate into other less demanding but also less significant channels.

The Scientific Program

The Earth System Sciences Committee (ESSC) is proceeding on the basis of a definition of the Earth System as made up of three major subsystems, the first two quite closely linked, the third somewhat more loosely. They are:

The fluid subsystem, comprising the physical aspects of the atmosphere, ocean and cryosphere.

The biogeochemical cycles, comprising the chemical and biological aspects of the entire planet.

The solid earth system, including the processes which shape the surface of the earth and the distribution of minerals and information on past climatic regimes.

The upper boundary is considered to be near the mesopause, at a height of about 80 km. There are important fluxes through this boundary. From above, the total solar energy, the ultraviolet radiation and intermittent inputs of energetic particles are significant variables for the system below. From below, the tidal and wave fluxes are major inputs into the upper atmosphere. However, the coupling between these upward and downward fluxes is relatively weak, and it seems sensible from the perspective of the ESSC, though not necessarily from that of the IGBP, to treat Solar and Space Plasma Physics as a separate subject, reviewed for adequacy of understanding the boundary fluxes, but with its own distinct program rationale and dynamics.

The relevant scientific strategy (at least for the space related aspects) has mostly been satisfactorily articulated in reports of the Space Science Board of the National Research Council and will not be discussed in detail here. For the fluid subsystem there is a consensus (at least in general terms) around this strategy within the relevant international community. However, I have the impression that it has been less thoroughly discussed internationally for the other two subsystems. It is thus essential that the opportunities presented by the IGBP for meaningful exchange both between scientists at the non-governmental level and in due course between governments be pursued as a matter of urgency.

Implementation

The task of orchestrating such program, even on a national basis, is daunting. Success will require the establishment and effective presentation of a consensus of many diverse interests, as well a realistic resolution of many technical and program issues within a total level of effort that is severely constrained by budgetary and institutional factors. Achievement of effective international consensus and action is even more difficult, yet will be greatly eased by having a strong, well conceived U.S. national contribution as a nucleus.

Major issues which need resolution include:

How best to structure the long term observations which are essential for understanding changes in the earth system over decades or longer. This question includes a very careful appraisal of priorities, the identification of and commitment by groups of competent individuals within an appropriate institutional framework, the choice of technology which can provide long term stability without inflexibility and procedures to assure adequate long term calibration and quality control. In addition, for each class of

observation the appropriate division of responsibility between the agencies has to be settled and widely accepted.

Much of the needed ongoing information is derived from data originally obtained for short term operational purposes. Particularly where expensive systems such as satellites or weather analyses are concerned, it is essential to find ways to work closely with such operations and influence their priorities where small changes would bring large benefits for the systems science. The commercialization of satellite land observing systems presents a different challenge, particularly where technique and instrument developments which are needed for scientific purposes might have commercial value. On the other hand, some much needed data may be available simply for purchase.

The scientific strategy for assessing the influence of terrestrial ecosystems on biogeochemical cycles calls for a blend of detailed in situ observations at carefully preserved test sites in all the major climatic and soil regimes of the world, coupled with the use of remote sensing to determine the spatial extent of the biomes represented by those sites. These sites will have to be in many different countries in all hemispheres. To be of real value they must be selected, funded and competently maintained with international access for several decades against the inevitable ravages of changing ##?personel and priorities, bureaucratic incompetence, budget crises, accusations of undercover spying and economic exploitation, etc. This task will test the resilience and institutional arrangements of the international umbrella for the program to the utmost.

The Earth Systems Sciences Committee

The ESSC has completed one third of a two year study, charged with recommending an implementation strategy for Earth System Science and defining an appropriate role for NASA in this area. It early concluded that considering NASA's role in isolation would be of little value. Instead it must define what is needed as an integrated U.S. effort in the context of anticipated international activities, working closely with representatives of all the affected U.S. agencies to foster all aspects of the program, and only at the end distinguish those aspects that are uniquely the responsibility of NASA. It also concluded that viewing the Earth as a system of interacting components does force one to take a fresh view of the component processes and assessment of priorities.

Its approach is to review and usually to adopt the basic scientific priorities from the Space Science Board, and to analyze the tools required to implement them in a reasonably cost effective manner, and assess how they fit together and the resources required. The tools include satellites, instruments, in orbit repair and retrieval, data handling, numerical models and in situ observations and research programs. The emphasis is naturally primarily upon the space related component, within a framework broad enough to assure the integrity of the whole effort. Considerable attention is also being given to the institutional issues and agency roles involved in a successful program that must be sustained for several decades to achieve its full potential, and must also relate successfully to other applications of the same observing techniques to shorter term problems.

Careful consultation at all levels is necessary during the formulation of the implementation strategy to foster a unity of approach among the three agencies primarily involved and the basis for collaboration with the others. Within NASA, key issues are the role for NASA in ongoing observations, the relationship of this program to Space Station, and the orderly evolution of instruments and techniques for the U.S. part of the Earth Observational System. In addition, with the National Academy of Sciences, efforts will be made to strengthen the framework for international collaboration through existing organizations such as the World Climate Research Programme and the proposed International Geosphere Biosphere Program.

Mr. VOLKMER. Rather than going to questions right now, we will recess for the vote and then be back and start the questioning at approximately 15 after.

[A short recess was taken.]

I would like to ask you a few basic questions as far as I am concerned, for my own edification.

Would you say that the International Geophysical Year of 1957–58 could be a model for the International Geosphere/Biosphere Program?

Dr. MALONE. In many respects it is. In other respects it is not. The IGY was a collection of observations made nationally linked together, but there was no program of the kind that involved global observations.

Second, the quantity of data now exceeds the capacity of the whole scientific community to assimilate it and we are going to have much larger problems of data management, but not beyond our technical ability.

On the other hand, in the sense that the IGY was planned by the scientific community, was actually run by the scientific community, with the support of governments, is a very attractive model.

Mr. VOLKMER. Dr. Bretherton?

Dr. BRETHERTON. I would comment that on the whole I agree, except that I would like to emphasize that so much of what we understand now about the global system comes from observations that were taken for other reasons as their primary purposes, that we should not fall into the trap of thinking that we are talking about a set of observations which are International Geosphere/Biosphere Program just independently of everything else that is going on. Probably by far the most effective way to do this is trying to find ways of harnessing some of the other observations which have already been taken and making them more valuable for the scientific purposes.

Mr. VOLKMER. At the present time we have other global international research programs, such as the World Climate Program, Global Environmental Monitoring System, Middle Atmosphere Program, International Kinetics Study, International Satellite Cloud Cover, Climatology Program, and others. The question is, do we really need the International Geosphere/Biosphere Program, and if so, how would it interact with these others?

Dr. MALONE. My answer would be yes, we do need another program and its focus should be on the interaction of these programs and not replacing these programs. In other words, what we need is something which will develop a synthesis and view the system in the holistic sense that Francis spoke about. I think the key word is interact, and not only the interaction of International Geosphere/Biosphere Program with the other programs, but International Geosphere/Biosphere Program should be the means by which the interaction of these programs with each other comes out.

Dr. BRETHERTON. I would agree.

Mr. VOLKMER. Now, how far along are we with International Geosphere/Biosphere Program. Is it any more than an idea at the present time?

Dr. MALONE. No sir, I would say it is not an idea—it is a proposal, and I am speaking at the international level—and at Ottawa

the decision will not be made to adopt it as a program, the decision that we expect will be authorization to proceed with the planning, with the objective coming before the General Assembly in 1986 with a specific program, and hopefully that will be persuasive, sound enough that it will then be adopted and become an official activity.

Mr. VOLKMER. At that time, as an official activity, or with an official status, would there be decisions as to the functioning of the program itself and the determination of who would be participating—what bodies would participate or individuals or scientists, how costs would be allocated?

Dr. MALONE. The way we handled that in the case of the Global Atmospheric Research Program was that the so-called scientific strategy was developed, an agreement reached within the scientific community, then a meeting of governments was held in Brussels to consider the program developed by the scientists, and at that time, the institutional mechanisms for running it and the willingness of governments to support it was articulated, yes.

I think one comment, too, that one of the successes of the Global Atmospheric Research was the World Climate Research Program, which is addressing part of the issues that we are talking about here—only part—the physical subsystem that I mentioned. At the present time there is one program within the World Climate Research Program which is actively collecting data from satellites spread around the world, the Indians, the Europeans, used to be the two geostationary satellites, in the United States the two polar orbiters, and the goal of that program is to establish the cloudiness overall. That is underway as an international program now and is being evolved in very much the way Dr. Malone is talking about.

There are also under discussion and close to the level of getting international commitments a program on the tropical ocean global atmosphere which is concerned with the very large fluctuations we see in tropical areas; the El Nino you may have heard of and its interactions, ramifications through the whole global atmosphere. That is at the level of what you might call advanced scientific planning at the moment, with commitments being sought from governments within the next few months.

So there is an ongoing process here but the World Climate Research program is relatively advanced in this area. When you get two things like the bio/geochemical cycles where there is a lot of interest spread around the world, I think there is a lot of, let me call it, thinking out how you do it and obtaining consensus, done within the United States that is not yet being fully accomplished internationally. We very, very much need to press forward with that to make sure that we have the right program balance.

Mr. VOLKMER. Dr. Bretherton, in your testimony at the end before we broke, you mentioned that you wanted to see, would like to see a national program. Now, by that, do you mean that we would have a national program separate from an international program?

Dr. BRETHERTON. No, I mean that we have a national initiative as part of an international program, but recognizing that the way you get an international program going on problems of this complexity is to have strong leadership, and the U.S. is probably the

only country that in this area is positioned to take really effective leadership. If we fritter our energies away, by essentially not being able to decide internally how to do things, the international program will not be successful.

Mr. VOLKMER. I would like again to go over one part of your answers to an earlier question so that I have it clear in my mind that you wish to use basically present technologies and present information data either that are presently available, rather than just going out and building a new system altogether or look at the existing problems, is that correct?

Dr. BRETHERTON. The situation is a mix. There is a very large amount of information to be obtained with the intelligent use and relatively small incremental costs from existing information sources and observations. However, there are critical gaps in the system, and there will be no alternative but to go out and deploy new systems to cope with those. In particular, there will also be major challenges in the area of data management and the basically drawing upon the existing data sources to extract new types of information from them.

Mr. VOLKMER. Should we now use the existing systems we have to demonstrate some successes?

Dr. BRETHERTON. In part I think that depends on how you define success.

Mr. VOLKMER. Right.

Dr. BRETHERTON. Inevitably.

If you look back over the last 20 years, one of the areas which has received a great deal of attention, that of weather predictions in various forms, I think we can claim substantial success—not overwhelming but substantial—certainly a level that is so commonplace we now take it for granted—the tracking of hurricanes and the early warning to individuals of and local governments of impending natural disasters of that sort, has clearly been very much advanced by the sort of observation you can get from space.

I think our ability to predict the weather on a sort of 48 hour time scale, 72 hour time scale is unquestionably better now than it was 10 to 15 years ago. So we have had successes from this type of activity in the past, but we must not imagine that sort of understanding that I am talking about will come quickly or easily.

Mr. VOLKMER. I will now yield to the gentleman from California for any questions he might have.

Mr. BROWN. Dr. Bretherton, you spoke in your statement of a kind of a boundary in the atmosphere, altitude of 80 kilometers, and I am interested in the elaboration of this concept, and particularly as to whether or not there is a physical significance to this, or if this is an arbitrary selection, and also whether it has any institutional meaning.

Dr. BRETHERTON. The answer is, all of the above. There is a physical significance, in the sense as you go higher up through the atmosphere, things on the whole become less closely coupled to what is happening down here at the surface.

There are major influences that propagate up, the atmospheric times, but on the whole, there is not enough mass of the atmosphere above 80 kilometers to make very much difference to what is happening down below.

We are critically dependent every day on the sun to warm the earth for us. One of the scientific questions we do not know the answer to is whether there may be changes in the total solar output, significant magnitude on time scales of one or two solar cycle 22 years, 11 years, or a few hundred years.

We don't really know the answer to that, and the only way we know that is by doing good solar physics. There are also outputs from the sun in terms of varying ultraviolet radiation and high-energy particles which are substantial in the lower part of the atmosphere, but these are relatively coupled questions.

The way you address them is by doing good solar physics and understanding solar wind as a phenomenon rather than forcing one's attack on the problem to be very closely related to saying, how do we predict tomorrow's weather?

Mr. BROWN. Let me explore a few other areas with you, and I am sure you know, I am very supportive of the idea of large-scale international-type scientific programs, for a number of reasons. But long experience with trying to develop effective programs at the governmental level has not encouraged me too much to be optimistic about the success of these.

In terms of, say, something like a resolution encouraging this, that is not a problem. It is when we try to create institutional structures and provide funding priorities that we get involved in all sorts of problems, and I need to explore in my own mind the rationale and the arguments, pro and con, not only so that I can know for myself, but to persuasively, to argue with persons who may not be as committed as I am to this type of approach.

For example, we have a national and world climate program. In many ways, it would overlap with this, because your climate programs are earth observation programs, producing a range of data which is constantly becoming more important.

What additional contribution do we make here that sets it apart from the global and national long-range climate research programs that we have?

Dr. BRETHERTON. The world climate research program is—which arose out of the global atmospheric research program, is a shining example, that this can be done internationally. It is very difficult, but it can be done, and what we see happening here is a broadening of the area covered.

The world climate research program is addressing one of the three or four sort of critical subsystems of this. It is a very important one, the way all the fluids move around, but not addressing directly the sulphur cycle and the carbon cycle and the nitrogen cycle that we realize have a very fundamental impact on the way the whole system works, and the sorts of changes that can arise.

The world climate program is taking those essentially as a given. We need to get a comparable effort in the other subsystems, particularly the bio-geochemical one, but I would include in here not neglecting the solid earth or the solid terrestrial area.

Mr. BROWN. Elaborate on that. What kind of observations are we talking about, the bio-geochemical system?

Dr. BRETHERTON. I will address the sort of scientific questions that arise.

Mr. BROWN. I have been interested in our agricultural observation program, for example, but that is almost an economic kind of program.

What is the status of the global crop—to project the market next year.

Dr. BRETHERTON. One of the side issues of global agricultural, the input of active nitrogen into the recycling part of the system, is currently believed to be about 40 percent higher than it was 20 years ago, due to man's output of fertilizer.

That has ramifications through the chemistry of the atmosphere up to the ozone cycle in the stratosphere, through all sorts of things, including ultimately the climate. That has ramifications that we are just beginning to see, and so, the first thing one has to do is to do is to know what are the sources of nitrogen, where is it going, how do the bacteria in the earth change it, et cetera.

These are the sorts of questions one has to come to grips with.

Mr. BROWN. This means we are talking about a combination of observation from space and observations on the earth itself.

Dr. BRETHERTON. Yes, sir.

Mr. BROWN. Are we concerned about gross observations of phenomenon like deforestations?

Dr. BRETHERTON. That is absolutely correct. We are concerned both with identifying the extent of things like the forests, and the fields and the tundra spread around the world, plus in addition, we have to have intensive in situ efforts spread around the climate zones of the world where you actually see what is going on in the individual ecosystems so you have a strategy in which you look at the individual ecosystems to get the rates of change to see what is happening in a small sample, and you space techniques to see how widespread those individual observations are.

Mr. BROWN. One result of a large-scale coordinated global program of this sort would probably be an intensification of scientific interest and the improvement and development of new scientific methodologies, instruments, of course, ultimately theories, so as to do both a better job of collecting data, and then of analyzing and theorizing about that data.

What has your thinking led to as the potential from this kind of improvement in scientific capability? I am thinking in very practical terms. Let me give you an example. The Defense Department is very much interested in ocean observation for the purpose of detecting submarines.

You may, as a result of the development of new processes for observing the globe, in particular the oceans, make a vital breakthrough in antisubmarine warfare, which will complicate your scientific problems to no end.

Dr. BRETHERTON. We are well aware of that type of problem. If we were to be really successful at it, we would be very pleased, but we are not that confident of our ability to get to that point.

Mr. BROWN. Are you going to have an interest in this program from other agencies such as the Defense Department who may want to constrain or modify or direct this program in various ways, because it does have application?

Dr. BRETHERTON. Yes, that is one of my concerns. Let's say, the concern is two-edged. It is first, one as to whether our own Defense

Department may say this is treading too close to what is strategically important from their point of view, and also, it is that the other countries of the world will feel that they are being exploited, or the program is being exploited to obtain information of either military significance to the United States, or to be used for, let's say, economic domination of those countries.

And as a result, we will lose international collaboration that way, because the heart of what we are talking about is the free exchange of data between the countries of the world and that has to be abundantly clear to those countries, that this is a problem which is in everyone's interests, including theirs, and that is free of any taint of military significance, and so we have a fine line to tread between using techniques that could potentially be used for revealing secrets.

Mr. BROWN. Are you going to, by resolution, better than 25 meters for any of this observation?

Dr. BRETHERTON. My personal judgment on this, the technical reviews on this are not yet in, my personal judgment is no, but this is very much a matter under study at this moment.

We certainly have another issue that I know this subcommittee is concerned with, and this is the correct relationship between government-sponsored research, and a market-driven application system.

One of my other concerns is that again, the more successful the scientists are with showing how some of this instrumentation can be used, the greater danger that someone in the system will say it has commercial value, and therefore, they shouldn't be doing it.

Mr. BROWN. Well, I have listened to scientists for years say that they were doing no commercial or military applications, and that was what Fermi would have said and the people who worked on lasers and various others.

It is an interesting theory, but the facts don't bear it out very well. There is a military or commercial application to what scientists do, even if it is just observing the area.

We have a very fascinating program under way now in the form of a space telescope, a very powerful instrument for looking outward, and you are proposing we look inward with tools of equal sophistication.

A major problem here, of course, is the data stream that results, the collection and management and organization and so forth, and it may be that a large part of the contribution this project might make would be the rationalization, scientific and technical data with regard to the Earth.

Is there a comparability here between the problems you would envision developing in this program and what we are wrestling with now resulting from the space telescope and its relationship to the telescopes?

Dr. BRETHERTON. The space telescope item is more complicated—well, there is only one space telescope. You are dealing with a relatively small group of scientists with a relatively homogenous set of data sources.

There is no other space telescope to put against that, of course, the surface, optical and radio telescopes and that sort of thing, which are giving complementary information, but one of the big

problems in organizing data flows in any effective way is understanding the sociology, the institutional structure of the people who are really using that data, analyzing it.

And what is more, who are doing things which add information to the data stream which has to be captured back and kept as data for other people.

It is that recapture process, value-added information is what we very often neglect. This is not an easy area, I will say that outright. I am hopeful that we can do a somewhat better job on this than we have in the past.

In fact, we have to, because the technology otherwise is rapidly getting beyond our ability to cope with it.

Mr. BROWN. Dr. Bretherton, for 5 years I have been concerned about the general problem of information management rationalization of scientific and technical data, whatever you want to call it.

I look on projects of this sort as an opportunity to contribute to a broader, what you might call a systems approach to this whole problem of handling data.

I would like to see that included a little bit in your thinking here, and maybe we can get more people to understand the importance of a coherent organization of the data base problem as a whole.

Dr. MALONE. That is a very important point, and we built that into our symposium. We have a special paper on data management, prepared by Dr. Hutchinson, who is chairman of CODATA, which is the instrumentality that worries about precisely the problem that you were addressing.

As we proceed, we must design the data management system that goes with it, or we would be in trouble.

Mr. BROWN. Well, I bring those questions up just so that you could at least indicate the direction of your thinking. They are much more complex.

Dr. BRETHERTON. I really do appreciate your concern on this. I can only assure you, actually, I spent the whole of yesterday and the day before wrestling on exactly this question, and it is very high in our thinking.

It is not, unfortunately, at a level at which I am able to say very much constructive about exactly what you need to do.

Mr. BROWN. Thank you very much.

Mr. VOLKMER. The Chair will now recognize the gentleman from Florida.

Mr. NELSON. Thank you, Mr. Chairman.

Dr. Malone, you had stated that at the proper time, "a concurrent resolution would be of enormous value." What do you think this resolution ought to say?

Mr. MALONE. Two things, that it is the will of Congress that this program be pursued; and second, asking the executive branch, particularly the President, to report yearly on the progress that has been made.

This kind of resolution was enormously effective in the Global Atmospheric Research Program; and when Dr. White came and testified before the appropriations and authorizations committees, this was very helpful.

In fact, the White House had to look at this thing and prepare a report, while it was enormously effective.

Dr. BRETHERTON. I would agree with that. I would emphasize the problem that one meets in trying to structure a program of this sort is the tendency for it to be everyone's second priority.

Everyone realizes it is very important and their part in it is very important, but it is always less pressing than something they got immediately at the top of their list, and as a result, it is very difficult to get a broad view among the various agencies.

And somewhere one has to create a focus that is able to bring those things together, and keep asking the hard questions and insist on getting a resolution of them.

Mr. NELSON. Thank you, gentlemen.

Thank you, Mr. Chairman.

Mr. VOLKMER. Dr. Bretherton, don't you really have that much of a problem on a national—if you didn't want to do a national as well as an international program, as far as getting the focus and getting everybody together?

Dr. BRETHERTON. I was responding in terms of a national level, as well as international.

Mr. VOLKMER. To get back to the question on the organization of the IGBP, from the testimony I heard here today, it would appear to me, again as an outsider looking in, that the IGBP could become an organizational structure formulated from the ICSU, is that correct or incorrect?

Dr. MALONE. I think that since the Government was involved, we need some kind of an intellectual driving system, and I hesitate to keep referring to GARP and the lessons we learned there, and the successes and failures we had there should be used.

We created a body of 12 scientists, six of whom were drawn from the intergovernmental community, and six from the scientific community. Six were nominated by WMO and six by ICSU.

That kind of an intellectual centerpiece has worked effectively, because the people were chosen not because of their affiliation, but because of their competence and experience with the problem.

And by and large, the governments have responded very well to the recommendations, and the program strategy that this group recommended. I have something like that in mind.

Mr. VOLKMER. You actually would be using the ICSU basically as a way to move the organizational structure you are talking about ahead?

Dr. MALONE. That is right.

Mr. VOLKMER. Therefore, separate and distinct?

Dr. MALONE. It is more complex here, because there will be several intergovernmental agencies involved here, and that gets very complex, I can assure you.

Mr. VOLKMER. It would have its own management team, et cetera, also, if it ever became functional?

Dr. MALONE. I would stress that, probably a large portion of this program will be nationally funded. That is the way these things operate, rather than create a super agency, it is the things like the joint organizing committee of 12 people which glue or hold together these national efforts.

Mr. VOLKMER. In other words, to go back to Dr. Bretherton's position that we have to have the national program?

Dr. MALONE. Yes; we have to have one, and at least a dozen other countries have to have one.

Dr. BRETHERTON. What it is critical to achieve through the international organizations is, first of all, a community of objectives, and second, the free exchange of information and data, and only third, I think to come down to the level of a humdrum level, but very important one, of cost sharing.

Mr. VOLKMER. How do we get these other nations involved? Excuse me, assuming we decide to move on it ourselves?

Dr. MALONE. The first step is to ensure that the scientists in the other nations want to do it, and that is what we are exploring in Ottawa. If they don't, we can't persuade the United Kingdom to get involved or the Soviet Union, unless the scientists want it. They have to go back home and be advocates as Francis and I are here.

Mr. VOLKMER. In order for us to get a national program on its way, you are going to have to persuade the various Federal agencies involved that we need to have a national program to do this, is that correct?

Dr. BRETHERTON. Yes; that is correct.

Mr. VOLKMER. That includes NASA, NOAA, and everybody else, and the witness from NSF testified, the key question for the National Science Foundation is whether the IGBP will encourage first-rate U.S. scientists to prepare first rate proposals to NSF for study for first-rate scientific problems.

Do you agree this is the key question?

Dr. MALONE. I would add young, first-rate scientists, because this will come into being in the 1990's and I will be pushing up daisies at that time, and first-rate young scientists, and I have talked with people like Volker Mohnen, Thomson Webb, and Meinrat Andreae, who are prepared to devote part of their scientific career to this program. The potential exists.

The problem is a key problem. If we don't have good young scientists in it, forget it.

Dr. BRETHERTON. I would agree, and I highlight the question states the key question for the National Science Foundation is that. There are many other important questions.

Mr. VOLKMER. As far as NSF is concerned, and their part of it?

Dr. BRETHERTON. If it is not good science, they are not interested, and we wholeheartedly agree.

Mr. VOLKMER. Do you believe there are good, young scientists out there right now willing to participate?

Dr. BRETHERTON. Unquestionably. There is enormous concern and there are a large number of scientists who are getting involved and are very keen to get involved, but can't quite see how to do it.

Mr. VOLKMER. Do you believe that the National Science Foundation role should be a passive one in this type of activity, or more active, or do you wish to answer that?

Dr. MALONE. I believe it should be an active one, because I can't stress strongly enough the necessity of a strong infrastructure of scientists around universities working on these problems.

An international program isn't just a bunch of satellites and big data centers and things of that kind. You have to have the infrastructure to support it, and that is the unique role of NSF.

And I think, far be it from me to tell them how to organize themselves, but as you know, the National Science Board has come out with a very positive statement about enhancing the role of the Foundation in international programs.

And I would hope that that would take a concrete form in incrementally adding dimensions to their various activities, which would permit the range of disciplines to be brought together and encouraged to work on these kinds of problems.

I would hope it would be more than a passive role. I would hope that the proposal pressure would be sufficient to persuade the National Science Foundation that yes, there is good science, and we should be—that that is their business.

Mr. VOLKMER. OK.

The gentleman from California touched on this a little bit, and you have in your prepared statements, about the large amount of data that this whole type of project would generate.

Do we envision that we are going to have a new central data bank for our national program, and England will have one, or do we envision that we will use existing data systems, or what do you envision?

I notice it is a little early.

Dr. BRETHERTON. I think unquestionably, one has to work through existing international channels to the extent possible, but we must also admit, quite frankly, that those channels are not always adequate.

Indeed, they are not always adequate for what is happening, and so there are going to be large computerized data bases spread through the various countries of the world, and probably spread through different parts of the same country.

The technology here is, though substantial and costly, is probably less significant than the human organization that lies behind those data bases.

The way you go from data to real information is a process of highly competent people analyzing that data, and drawing important conclusions from it, and summaries from it, which in their turn form the important material for further studies and further analyses, and unless we are able to involve that type of hierarchial structure in our information system, you are not able to come to grips with these large-scale systems that we are discussing here.

The reason is very simple, as already mentioned, no individual, however gifted, can possibly be expert across the whole range of these problems, of the problems he needs to be an expert across to understand, and so the key question is how one brings back into the information system and make sure they are a real integral living part of it for everyone else to draw upon.

Many of the interpretations and analyses and hard work is done by other individuals.

Mr. VOLKMER. Do we need to have a centralized data bank system for all this data to do that?

Dr. BRETHERTON. My view is most of it will be decentralized, but there will be some centralized data places. It is hard to give, for

me, to give an answer that convinces me of that question at this moment.

Dr. MALONE. There is a point we should keep in mind. There is an invaluable control mechanism that obviates the possibility that we would be drowned in data, because this could happen, since we have the capacity to gather more information than the whole world scientific community can digest, and that is to insist that data collection be aimed at resolving a specific scientific problem.

And if that is exercised throughout, that will keep this data problem, I think, tracked.

Mr. VOLKMER. Would you anticipate that the IGBP, assuming it would be formalized into an organizational structure, would be the manager of this data system, or would each national group manage their own system?

Dr. MALONE. In the world today, I believe national management will be the answer. It was the answer in the IGY, World Data Center A&B, it worked extremely well.

Dr. BRETHERTON. What is essential is the international agreement that facilitates exchange between those national structures. That is the place which is very difficult to achieve, not only between governments, but between individuals or organizations.

Mr. VOLKMER. If there is a scientist in France that wanted data from a program here in the United States, to go along with data that he thought was necessary for the United Kingdom, that he be given the ability to access that and obtain that information?

Dr. BRETHERTON. The ability and also the formats, the way that data is organized be common between the various countries, so that is a relatively easy task. It is not one of sheer technical ability to communicate bits from one place to another.

Much more, it is a matter of the organization of the data base, for the formatting of the numbers and that type of thing.

Mr. VOLKMER. Dr. Bretherton, I want to get back to the question of the gentleman from California, the boundary in the atmosphere, altitude of 80 kilometers. What is the physical significance of the boundary? It has less impact on most things, except for the sun. I remember that.

Dr. BRETHERTON. I forget the precise proportion, but I believe it is less than one part in 10,000 of the mass of the atmosphere is above that boundary, and if you are trying to understand how the system works, there is a good case being said for ignoring that mass, it is unimportant, but there are some exceptions to that.

When you identify the exceptions, they come through the impact of the sun, the total radiation from the sun. They come through the ultraviolet radiation which can directly affect the ozone and whole physics of the upper atmosphere, and the high-energy products.

There are significant influences passing through that boundary, and to understand what happens below, you can't ignore what is happening above, but you can apply some fairly clear criteria as to what are the details of what is happening above, what is important to you and what is not.

Mr. VOLKMER. What is the institutional significance of this boundary?

Dr. BRETHERTON. As you already commented, our major programs, not only in looking at the world climate research program, but also the middle atmosphere program, the international magnetospheric study.

Each has different groups of advocates, and where you are dealing with space technology, they are advocating hard or new starts within a total NASA budget, which is constrained, and there is a big question about the appropriate sequencing of programs of major efforts of this sort which require large commitments of resources.

Those are coupled also to the fact that within NASA, within the Office of Space Science and Applications, there are basically three major program groups, one of astromony, planetary exploration and Earth looking sciences, and there has been considerable debate about whether the present grouping of solar terrestrial—the Earth-looking science is the appropriate one.

Because of the history of this, because of setting up the Earth systems science committee, a deliberate decision was made to treat the planning process, solar terrestrial, as distinct from the Earth system, although from one programmatic point view, you could have included it.

Another point of view, you could say it was weakly coupled. There is a long history of that which colors the way I use my words.

Mr. VOLKMER. Dr. Malone, do you wish to comment?

Dr. MALONE. At the present time, the international program embraces both, the sort of terrestrial domain, the near-Earth domain. How that will shake out over the next 2 years, I can't conceive, but at the moment, it is all one system.

Mr. VOLKMER. I want to thank both of you for your testimony here today, and you have been very helpful, and as we go on with this, I am sure that the committee will continue to look at it and I agree with you, that we need to have a strong national program, Dr. Bretherton, and we will do what we can about it, and eventually maybe we will have an international program and we will know, maybe. Like you said, I probably won't be there either, Dr. Malone, but it is insignificant, time of man, and I think it needs to be done.

With that, we will adjourn, and we will meet again tomorrow at 10 a.m. in room 2325 for further testimony.

[Whereupon, at 3:10 p.m., the subcommittee recessed, to reconvene at 10 a.m., Thursday, September 13, 1984.]

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INTERNATIONAL GEOSPHERE/BIOSPHERE PROGRAM: 1984

THURSDAY, SEPTEMBER 13, 1984

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS,
Washington, DC.

The subcommittee met, pursuant to call, at 10:30 p.m., in room 2325, Rayburn House Office Building, Hon. Harold L. Volkmer (chairman of the subcommittee) presiding.

Mr. BROWN [presiding]. The subcommittee will come to order.

I am somewhat apologetic at the fact that the Caucus of the Democrats has imposed upon our Republican colleagues, as well as our witnesses this morning, and I am undertaking to begin the hearing in order to alleviate some of that embarrassment. I trust that Mr. Volkmer will return shortly and will be able to continue with the operations.

[There was a brief business meeting of the subcommittee unrelated to these hearings.]

Mr. BROWN. Now we will proceed to the hearing itself. Mr. Volkmer had a brief opening statement, which I'll be happy to read for him.

The subcommittee is happy today to welcome some agencies that we do not normally hear from. Doctors Tilford and McElroy from NASA and NOAA respectively are old friends of the subcommittee, but I believe this is the first time we are welcoming Dr. Trivelpiece and Dr. Bridgewater from DOE and NSF respectively.

The full committee put language in legislative reports instructing the four agencies here today to support the IGBP.

Dr. Trivelpiece in his prepared statement clearly states the Department of Energy supports the "concept," but that the Department wants to see whether "links between areas of study are strong enough to justify on IGBP."

Of course, we should not have a program unless it is justified, but I believe that the committee's intention in writing the report language was to encourage the agencies to reach out and touch—to make the IGBP concept work.

Today we hope to hear how you are doing this.

Mr. BROWN. You're all up there waiting patiently to move, so you may proceed.

I'm sorry, I just——

Mr. LUJAN. Just in the interest of time, Mr. Chairman, I would ask unanimous consent that my statement be included in the record. It speaks primarily of the problems of cooperation that we will have because of the——

Mr. BROWN. Without objection, that will be done.

[The opening statement of Mr. Lujan follows:]

OPENING STATEMENT OF THE HONORABLE MANUEL LUJAN, JR.

Thank you, Mr. Chairman. The International Geosphere/Biosphere Program is a perfect example of the type of programs we can expect to see more of in the future, because it involves interdisciplinary, interagency, and international coordination and cooperation. The history of the space program is full of examples of cooperative efforts. These cooperative efforts have taken both the form of cooperation with NASA and other Federal agencies and cooperation with other countries. In addition there is a strong tradition of cooperation with other institutions involved in science and technology, such as universities and industry. But the degree of cooperation that will be required for the International Geosphere/Biosphere Program to be a success will be more than we have seen traditionally in such cooperative programs. Although this greater level of cooperative efforts will certainly be a challenge, it also should be viewed as an opportunity. Future programs in science are almost certain to require greater levels of cooperation and coordination. This is partly because the cost of science has increased as the sophistication of our understanding and knowledge has increased. We will want to cooperate with other countries because then we can support more research for the same amount of taxpayer dollars. Thus we can maximize our knowledge and minimize our costs.

Another reason that future research programs are certain to require greater levels of coordination and cooperation is the increasingly interdisciplinary nature of science. The International Geosphere/Biosphere Program is a particularly good example of an interdisciplinary program. This program presents us with an opportunity to improve our mechanisms for coordination and for organizing cooperative efforts.

For these reasons I am a strong supporter of IGBP and I will be following its progress closely. I certainly encourage the agencies to work together to ensure the program is a success and is a successful model of interdisciplinary, interagency, and international coordination and cooperation.

Thank you, Mr. Chairman.

Mr. BROWN. Now, gentlemen, shall we take you up in the order that you're listed. Dr. Tilford, you may begin.

STATEMENTS OF DR. SHELBY G. TILFORD, DIRECTOR, EARTH SCIENCE AND APPLICATIONS DIVISION, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, WASHINGTON, DC; DR. JOHN H. McELROY, ASSISTANT ADMINISTRATOR FOR ENVIRONMENTAL SATELLITE, DATA, AND INFORMATION SERVICES, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, WASHINGTON, DC; DR. ALVIN W. TRIVELPIECE, DIRECTOR, OFFICE OF ENERGY RESEARCH, U.S. DEPARTMENT OF ENERGY, WASHINGTON, DC; AND DR. ALBERT L. BRIDGEWATER, ACTING ASSISTANT DIRECTOR, NATIONAL SCIENCE FOUNDATION, WASHINGTON, DC

Dr. TILFORD. Thank you, Mr. Chairman.

Mr. BROWN. Again, I apologize on behalf of the chairman.

Dr. TILFORD. Thank you.

I am pleased to be here today to discuss the IGBP Program and the status of NASA activities related to that program. I have pre-

pared a written statement which, with your permission, I will summarize.

Mr. BROWN. Without objection, the full text will appear in the record.

Dr. TILFORD. The National Academy of Sciences proposed the International Geosphere Biosphere Program, which would be a research program conducted under the auspices of the International Council of Scientific Unions, ICSU. The process of definition, after this program is submitted to the General Assembly in Ottawa later this month, will take approximately 2 years. However, we believe that the broad concepts of this program and NASA cannot assess completely how this will achieve its goals, IGBP with respect to NASA, until the program is fully defined. However, in consideration of the broad goals now being considered for this program, as discussed by Mr. Malone earlier, NASA is in full support of this program.

Earlier, NASA and the scientific community have realized that in order to study the Earth as a system, it is necessary to look at the coupling between the land, the atmosphere, the oceans and the biosphere. These are all coupled on time scales of a decade or longer.

A couple years ago, with this view in mind, NASA took the lead and initiated a series of workshops to define the scope of such a research program, which we call global habitability, with a goal to investigate the long-term coupled physical, chemical, and biological changes in the Earth's environment on a global scale.

The NASA administrator first proposed this concept of an interdisciplinary research program in Earth sciences at the Unispace '82 Conference in August 1982. Since that time, we have held a number of additional workshops to further define concepts for such a program.

In addition, one of the eight Agency goals and objectives adopted by NASA in the past year is to conduct an effective and productive space and Earth sciences program, with one of four objectives defined as, by 1985, establish, in cooperation with the scientific community, other Federal agencies, and international organizations an active long-term Earth sciences program—that is, global habitability.

This will require a comprehensive Earth science research program involving space-based, but also suborbital, land-based and sea-based measurements; laboratory, theoretical and instrument and model development studies, with national and international cooperation.

The Academy has agreed to undertake an assessment of NASA's global habitability workshop reports to assess the intellectual content, relevance and importance of this approach, and to assess how such a concept fits into the ongoing and planned programs, including the IGBP, plus those other ongoing programs, such as the world climate research program, et cetera.

As a first step toward implementing such an interdisciplinary research activity, NASA will issue within the next few weeks a Dear Colleague letter announcing new opportunities to scientists worldwide to participate in this new expanded area of interdisciplinary research science.

In addition, an announcement of opportunity was released last month describing an opportunity for the international scientific community to propose scientific investigations which might be carried out utilizing for the first time the thematic mapper data from the Landsat-4 and Landsat-5.

In order to proceed more rapidly than the IGBP will be able to, NASA is proceeding internally to prepare for the implementation of such an integrated Earth science program. NASA has initiated the Earth System Science Committee, a subgroup of the NASA Advisory Council, to review the whole of the Earth science and applications area, and to define those areas that need further research, define both NASA and NOAA's roles in such, and to establish priorities for these elements of the total program that need to be addressed in the next decade. This was discussed in some additional detail by Dr. Bretherton yesterday.

The one element which this committee will not be addressing is the solar physics, space plasma physics arena. However, simultaneously with this, the Space Science Board's Committee on Solar and Space Plasma Physics, with inputs from the NASA Committee on Solar Terrestrial Research, are doing the same process for those elements of the space plasma and solar physics area.

In the past year, NASA has proposed and the Congress has approved the UARS program, an improved scatterometer to be flown on the NROSS satellite with participation by NOAA and NSF, and the initial phase of an interdisciplinary research program. As part of its future activities, NASA is considering TOPEX, a precise altimeter to be flown in the early 1990's elements of the International Solar Terrestrial Physics Satellite Program, which is an international program of the US, ESA and Japanese participation; and to enhance other elements of programs which can contribute to IGBP. A good example is the successful nature of such cooperative activities as the international satellite cloud climatology program, which I believe Dr. Bretherton discussed in a little bit of detail yesterday.

I believe that the data from the current ongoing NOAA operational systems, from future operational oceanographic systems, from current surface and subsurface measurements and some enhancements of relevant areas of NASA's, NOAA's, NSF's and other agencies' research programs and planned flight missions, such as GRM, and especially the space station polar platform which we are looking at in terms of the Earth Observing System, plus a future Geostationary Earth Observing System, are required to implement programs like IGBP and global habitability.

For many elements of these long-term programs, continuous data are mandatory in order to observe and assess long-term changes and processes. We must have continuous data sets. We will continue to coordinate with NOAA, other Government agencies and the private sector to try to insure that such data will be available to the scientific and research communities.

With respect to the Earth Observing System, we have spent quite a bit of time in the past 18 months—we've established an extensive scientific working group consisting primarily of university scientists to define those elements of space station solar platform, which would contribute to an Integrated Earth Science and Applications Program. A report of this concept, which encompasses many of the

objectives of the proposed IGBP and global habitability, has just been published, and we have forwarded copies of this report to your staff.

This working group made several recommendations, including the following: the Earth Observing System should be established as an information system, not just a measurement system; present time series of Earth science data must be maintained and continued; a data system that provides easy, integrated and complete access to past, present and future must be developed; and a long-term research effort must be sustained.

As part of any future interdisciplinary, integrated Earth science programs, we believe, in agreement with many recent recommendations, including those from this committee, that work should now begin to explore requirements for a future interactive global resource information system. We have initiated a number of pilot programs to attempt to achieve these objectives, including the Ocean Pilot Data System, the Land Pilot Data System, the Space Plasma Physics Data Network, et cetera.

Additionally, in the past year, NASA and the United Nations Environmental Program, UNEP, working with the Department of State, have signed a cooperative agreement to establish and demonstrate a Global Resource Information Data Base System. NASA will provide existing soft—hardware, develop the appropriate software, and provide some remotely observed to GRID. UNEP will provide the facilities, support the operational system, and provide global and in situ data bases to this system.

We believe that each of these efforts will provide and define the user inputs and requirements in a systematic manner in order to develop a comprehensive Global Resource Information System. We are discussing with NOAA, NSF, internal NASA committees and the universities, and various committees and panels of the National Academy, their requirements for such a system that will support IGBP in global habitability. We will report to you early next year, as you requested, on the progress in these areas.

As described earlier, NASA fully supports the IGBP concept and approach. We have provided, and expect to continue to provide, financial and programmatic support to the Academy and to the study committees formulating the IGBP Program.

Mr. Chairman, that concludes the summary of my prepared statement. I will be happy to answer, or at least try to answer, any questions you may have. Thank you.

[The prepared statement of Dr. Tilford follows:]

Statement of

Dr. Shelby G. Tilford
Director, Earth Science and Applications Division
Office of Space Science and Applications

National Aeronautics and Space Administration

Mr. Chairman and Members of the Subcommittee:

I am pleased to be here today to discuss the International Geosphere/Biosphere Program, and the status of NASA activities related to that program. I have prepared a written statement for the record, which, with your permission, I will summarize.

The National Research Council - National Academy of Sciences proposed the International Geosphere Biosphere Program (IGBP) which would be a research program conducted under the auspices of the International Council of Scientific Unions (ICSU). The process of definition will take at least two years after the ICSU General Assembly meeting which will discuss the concept of an IGBP in Ottawa, Canada on September 25-27, 1984.

In order to study the processes which lead to physical, chemical and biological changes of the Earth on a global scale, it has been realized by the scientific community, and by NASA, that it is necessary to study the Earth as an integrated system, because the land, the atmosphere, the oceans, and the biosphere are coupled on the time scales of a decade or longer. This study will require an interdisciplinary research program with international cooperation and participation. With this view in mind, NASA took the lead and initiated a series of workshops to define the scope of such a research program called "Global Habitability" of which the goal is to investigate long term coupled physical, chemical, and biological changes in the Earth's environment on a global scale. This program will focus on the major biogeochemical cycles [carbon (C), nitrogen (N), phosphorous (P), sulfur (S), and water (H_2O)], their impact on the global climate, and the factors judged to be important for the global life support system including solar variability and particle input to the upper atmosphere.

The NASA Adminstrator first proposed this concept of an integrated interdisciplinary science approach to Earth Sciences, with national and international cooperation and participation, at the Unispace '82 Conference in Vienna, Austria in August, 1982. This was preceded by a

summer study conducted at Woods Hole to investigate the feasibility of such a concept. Since that time a number of smaller workshops have been convened to develop further the rationale and elements of such a program.

One of the eight Agency "GOALS AND OBJECTIVES" adopted by NASA in the past year is to "Conduct an effective and productive Space and Earth Sciences Program which expands human knowledge of the Earth, its environment, the solar system, and the universe" with one of four major objectives defined as: "By 1985, establish, in cooperation with the scientific community, other federal agencies, and international organizations, an active long-term Earth Sciences Program (e.g., Global Habitability)."

To accomplish this goal will require a comprehensive Earth Science Research Program involving space-based, suborbital, land-based, and sea-based measurements; laboratory, theoretical, and instrument and model development studies, with national and international cooperation and participation. The approach to implementation of a Global Habitability Program is to continue relevant on-going NASA research programs such as solar-terrestrial research, upper atmospheric research, atmospheric dynamics and radiation, and oceanic processes; expand other relevant programs such as global biology, tropospheric chemistry, and climate; refocus the land processes program, and initiate an Interdisciplinary Research Program which will advance research in important areas lying between existing discipline areas or those that are critically involved in more than one of them.

As a first step toward implementing such an interdisciplinary research activity, NASA will issue within the next few weeks a "Dear Colleague" letter announcing new opportunities for scientists worldwide to participate in this new, expanded area of Interdisciplinary Earth Science research. Three areas of research have been chosen for initial study which are representative of the kind of research to be performed within the Interdisciplinary Research activity. These are particularly important problems on which progress can be made, while complementing ongoing activities in other related Earth Science programs. These three areas will be :(i) a program of research to understand the reasons for the recently discovered increasing trend in the atmospheric concentration of methane, and the long term consequences of the increase if it continues, (ii) a land-surface climatology program which is aimed at determining the extent to which changes are taking place in climatologically important properties of the land surface, to quantify those changes in physical and biological terms, to determine the important processes which control the changes, and to determine the overall stability of the coupled land-climate system, and (iii) an ocean basin scale carbon flux program which will develop a better understanding of the magnitude, variability, and fate of carbon fluxes in the oceans on an ocean-basin to global scale, and the role of oceanic carbon fluxes in global scale biogeochemical cycles and climate. These three areas have been chosen based on discussions held at a series of scientific workshops which considered these areas due to their importance and the fact that the scientific community is ready, we believe, to make substantial progress in them. Also, they represent the

type of scientific diversity that the Interdisciplinary Research Program will embrace, i.e., chemical, biological, and physical processes of the ocean, atmosphere, biosphere and land with emphasis on the biogeochemical, water, and energy cycles.

In addition, an Announcement of Opportunity (AO) was released last month describing an opportunity for the international scientific community to propose scientific investigations which might be carried out utilizing the Thematic Mapper data from the Landsat-4, and -5 satellites. This is the first opportunity for the general university and scientific community to take advantage of this data for scientific investigations. We expect that many of the responses will be related to the goals and objectives of the Global Habitability concept and proposed IGBP programs.

The National Academy of Sciences has agreed to undertake an assessment of NASA's Global Habitability workshop reports to assess the intellectual content, relevance and importance of this approach and to assess how such a concept fits into the World Climate Program, the World Ocean Climate Experiment, and other national and international programs, both ongoing and planned, including the International Geosphere Biosphere Program (IGBP).

Until the IGBP program is defined in its final form, specifics on how it will assist NASA in achieving its goals cannot be fully assessed. However, it is presently possible to make some general statements about the relationship of NASA's programs to the broad goals now being considered for IGBP. These range from a program encompassing all scientific issues from the center of the Sun to the center of the Earth, to a much more limited program focussed on global change with its emphasis on natural and "man-induced" changes on the decadal time frame. If the latter approach were to be the basis of IGBP, it would be completely consistent with the NASA Global Habitability concept and some limited elements of Geodynamics/Geology (sediment analysis), Space Plasma Physics (energetic particle input to atmosphere) and Solar Physics (solar output). An alternate approach to IGBP which has been discussed would be a multi-strand approach of three parallel, but essentially separate program components which encompass all of the Earth Sciences that are only loosely coupled, i.e., (i) Geodynamics/Geology, (ii) Land/Ocean/Atmosphere/Biosphere/Climate (Global Habitability), and (iii) Space Plasma Physics/Solar Physics programs. This latter three-tier approach is consistent with the organization of NASA's Earth Science and Applications Program within the Office of Space Science and Applications, where there are ongoing programs in each of these areas. One advantage of the three-strand program approach is that if a testable, tenable hypothesis concerning relationships between our climate and variations in solar radiation or the Earth's magnetic field or rotation rate (for example) are proposed, these could easily be adapted into the IGBP. I should add that, to the best of our knowledge, there has been no viable relationship proposed between the Sun and our weather that could be tested in a definitive manner.

NASA believes that the three-tier or three-strand approach is the appropriate way to proceed with the IGBP - consistent with NASA's Earth

Science and Applications Program [coupling within each element can be easily interconnected---coupling between elements is somewhat less obvious and interactive components (with some few exceptions) are not presently easily identified:].

SOLID EARTH SCIENCE PROGRAM
(GEODYNAMICS/GRAVITY/MAGNETISM)

NASA ——
Earth Science
& Applications
Program (ESAP)

GLOBAL HABITABILITY
(ATMOSPHERE/LAND/OCEAN -
PROCESSES PROGRAM)

—— IGBP

SPACE PLASMA PHYSICS/SOLAR PHYSICS
(ISTP)

The solid Earth is an important part of the IGBP as it is presently conceived. The sedimentary rocks contain the record of past climatic variations (as the geologists say, they own the IGBP library), and there is mounting evidence that the solid Earth is dynamically coupled to the oceans and the atmosphere in significant but as yet poorly understood ways. For example, volcanoes inject large quantities of gases and dust into the atmosphere which can significantly affect both weather and climate. The Earth's environment in the Solar System is profoundly influenced by the Earth's magnetic field and it is only through satellite measurements of the magnetic field that its long-term changes, which are of importance to human society, can be determined. The NASA Magnetic Field Satellite (Magsat) confirmed in 1979 that the strength of the Earth's magnetic field is steadily diminishing, and if it continues at that rate, the field would vanish in slightly more than one thousand years. At that time, the Earth's surface will be exposed to the full impact of the Sun's solar wind.

NASA's solid Earth Sciences programs are an integral part of cooperative international research programs such as the ICSU International Lithosphere Program (ILP). Through our precise measurements of the deformation and movement of the Earth's crust and our measurements of the Earth's global gravity and magnetic fields, ILP is the largest international program ever undertaken in the solid Earth Sciences, and its leaders are cooperating fully in helping to define and establish the IGBP.

In order to proceed on a more rapid timescale, but in parallel with the IGBP program definition activities, NASA is proceeding internally to prepare for the implementation of such a program. NASA has initiated the Earth System Science Committee (ESSC), a subgroup of the NASA Advisory Council, to review the whole of the Earth Science and Applications area (with the exception of the Space Plasma Physics/Solar Physics area which the Space Science Board's Committee on Solar and Space Physics (CSSP)is reviewing in a similar manner, with inputs from the NAS's Committee on Solar Terrestrial Research, (CSTR), to define those areas that need further research, to define NASA's and NOAA's

(National Oceanic and Atmospheric Adminstration) role in such, and to establish priorities for these elements of the total program that need to be addressed in the next decade. This Committee, using inputs from the National Academy of Sciences and other NASA, NOAA, NSF, etc. workshop and committee reports, will also address the roles and efforts of other agencies, i.e., the National Science Foundation (NSF), the Department of the Interior (DOI), the Department of Energy (DOE), the Environmental Protection Acency (EPA), the Department of State (DOS), and others, but will emphasize those elements that NOAA and NASA should focus upon in the next decade. This effort is fully supported by NOAA and two Assistant Administrators of NOAA are full participants in the ESSC. Representatives from the NSF and the DOI also serve as members of the ESSC. A staff member of the NAS, and representatives of other Agencies participate as observers.

Numerous interagency committees, e.g., the Subcommittee of Atmospheric Research (SAR) of the Committee of Atmospheres and Oceans, the Ocean Principals (composed of the Administrators of NOAA and NASA, the Director of NSF, and the Undersecretary of the Navy), the Interagency Committee on Ozone Protection (ICSOP), etc., as well as close communications and coordination between Program Managers and Discipline Chiefs within the different agencies have provided effective cooperation in many areas of Earth Science. Recently, the Office of Science and Technology Policy established an Interagency Coordinating Committee on Solar-Terrestrial Research (ICCSTR) under the Federal Coordinating Council on Science Engineering and Technology (FCCSET). This new Committee will report to the Office of Science and Technology Policy (OSTP) and will act as a coordinator, clearing-house, and evaluator of Federal research efforts on designated solar-terrestrial research projects. It will also coordinate agency plans for participation in international programs in solar-terrestrial research. Dr. Richard G. Johnson, Assistant Director for Space Science and Technology of OSTP will serve as Chairman, and Dr. Burton I. Edelson, the Associate Adminstrator of the Office of Space Science and Application of NASA will serve as Vice-Chairman of this Committee. The Committee includes representatives from all agencies involved in solar-terrestrial research.

In the past year, NASA has proposed and the Congress has approved the Upper Atmospheric Research Satellite (UARS) Program, an improved scatterometer to be flown on the U.S. Navy's NROSS satellite with participation by NOAA and the NSF, and the initial phase of an Interdisciplinary Research Program. As part of its activities, NASA is considering TOPEX (a precise oceangraphic topography satellite mission with major international participation); elements of the ISTP (International Solar Terrestrial Physics) Satellite Program, a jointly defined program with participation by the U.S., the European Space Agency (ESA), and the Japanese Space Agency (ISAS); and enhancements to other elements of programs which would contribute to the proposed IGBP. A good example of the successful nature of such cooperative international activities is the ongong International Satellite Cloud Climatology Project (ISCCP). The ISCCP, which began in July 1983 as the first project of the World Climate Research Program, is directed at establishing a five-year global cloud cover data set from the network of

meteorological satellites operated by the U.S., ESA, Japan, and India. NASA plays a central role in the ISCCP through support of the Global Processing Center which collects and processes the data from all involved satellites. The data sets produced by the ISCCP will permit major improvements in climate models. In a related area the U.S. (NASA, NOAA and NSF) will be sponsoring the First ISCCP Regional Experiment (FIRE) as a national project focusing on the scientific interpretation and applications of ISCCP data.

In order to implement Global Habitability adequately and subsequently support the proposed IGBP I believe it will be necessary to maintain our current capabilities in surface, sub-surface, and other operational satellite observations in order to further enhance certain areas of our (NASA, NOAA, NSF, and other agencies) Research and Analysis (R&A) Program: e.g., Land Processes, Interdisciplinary Research, Climate, Tropospheric Chemistry, etc. Planned flight missions such as the Magnetic Field Measurements Explorer Mission, the Geopotential Research Mission (GRM), the Space Station Polar Platform (EOS-the Earth Observing System) and a future Geostationary Earth Observing System will be necessary in future years to support the proposed IGBP.

The operational meteorological satellites, the NOAA and GOES series, together with NASA experimental satellites, Nimbus-7 and the Earth Radiation Budget Satellite (ERBS) (to be launched next month), provide atmospheric and oceanographic data essential for continuous measurement of the neutral lower atmosphere dynamics and the earth radiation balance needed to understand longer-term climatic changes and trends. ERBS is one element of a three-satellite system designed to provide the time and space sampling necessary for understanding the details of the energy balance that exists between the Sun, the Earth, and space; the other two elements are the operational polar orbiting meteorological satellites NOAA-F and -G, which are equipped with identical sensors. The Earth's radiation budget is of critical importance to the study of climate change as it provides a direct measurement of the basic sources and sinks of the energy which drives the motions of the atmosphere and oceans. NOAA also operates the Landsat satellites which provide the high resolution imagery required for land surface processes studies and for commercial uses. We believe that the data from these ongoing operational systems, from future operational oceanographic systems, and from current surface and sub-surface measurements are required to implement programs like IGBP and Global Habitability. For many elements of these programs, continuous data are mandatory in order to observe and assess long-term changes and processes. We will continue to coordinate with NOAA, other government agencies, and the private sector to try to insure that such data will be available to the research community.

With respect to the Earth Observing System (EOS), throughout the past eighteen months, NASA has established an extensive scientific working group, consisting primarily of university scientists specializing in most aspects of the Earth Sciences, to define elements of the Space Station Polar Platform which would contribute to an integrated Earth Science and Applications Program. A report on this concept, which encompasses many of the objectives of the proposed IGBP and Global Habitability, the "Earth Observing System (EOS)" has just

been published and we have forwarded copies of this report to your staff. This committee made the following recommendations:

- A program must be initiated to ensure that present time series of Earth Science data are maintained and continued. Collection of new data sets should be initiated.

- A data system that provides easy, integrated, and complete access to past, present, and future data must be developed as soon as possible.

- A long-term research effort must be sustained to study and understand these time series of earth observations

- The Earth Observing System should be established as an information system to carry out those aspects of the above recommendations which go beyond existing and currently planned activities. (Serve as a focal point for the observation and study of earth processes, functioning as the lead node or site within a distributed scientific and information network.)

- The scientific direction of the Earth Observing System should be established and continued through an international scientific steering committee.

As part of any future interdisciplinary, integrated Earth Science program NASA believes, in agreement with many recent recommendations, that work should begin now to explore requirements for the future interactive Global Resource Information System. NASA has initiated a number of pilot programs to establish user requirements, formats, how to archive and retrieve existing data and data bases - some of which include both remote and in situ type measurements, and how to transfer and communicate with these data base systems. These include a Pilot Ocean Data System, a Pilot Climate Data System, a Pilot Land Data System, the ISSCP data archive, and elements of a Space Plasma Physics Data Network (SPAN). Additionally, NASA and the United Nations Environmental Program (UNEP), working with the Department of State, have signed a cooperative agreement to establish and demonstrate a Global Resource Information Database (GRID) system. NASA will provide existing hardware, develop the appropriate software, and provide some remotely observed data to GRID. UNEP will provide the facilities, support the operational system, and provide global and in situ data bases to GRID. The initial emphasis of this system will be to provide access to researchers and resource managers in developing countries on a timely and comprehensive manner. We believe that each of these efforts will provide and define the user inputs and requirements in a systematic manner in order to develop a comprehensive Global Resource Information System. We are discussing with NOAA, NSF, internal NASA/University committees, and various Committees and Panels of the NAS, their requirements for such a system that will support Global Habitability and the proposed IGBP. We will report to you early next year, as you requested, on the progress in these areas.

As described earlier, NASA fully supports the IGBP concept and approach. We have provided, and expect to continue to provide, financial support to the NAS, to the two IGBP Woods Hole summer studies, and to the study committees formulating the IGBP program. NASA has fully supported and participated in, as observers and by providing information and background at the two IGBP Woods Hole summer studies. NASA has fully supported the NAS Board of Atmospheric Sciences and Climate (BASC) in their deliberations and formulation of the IGBP program.

Thank you, Mr. Chairman. That concludes my prepared statement. I will be happy to answer any questions you may have.

Mr. VOLKMER. Thank you very much, Dr. Tilford.
Mr. McElroy, you may proceed—Dr. McElroy.
Dr. MCELROY. Thank you, Mr. Chairman.
With your permission, I will summarize my testimony and offer the full statement for entry into the record.
The National Oceanic and Atmospheric Administration is actively involved in all of the scientific disciplines of the IGBP. Our involvement extends from service functions that generate both required and ancillary data for the IGBP to research programs that create a new understanding of the scientific basis for the IGBP, and on to national data archives that retain our historical records of environmental data and which will eventually be a repository for a large part of the data generated by an IGBP.
It's often been said that NOAA's responsibilities and interests extend from the surface of the sun to the core of the Earth. That isn't a bad way to describe the extent of the proposed IGBP. If we categorize the proposed program into four major discipline areas, it's easy to see how NOAA's efforts are included in each. Those areas might be stated as solar-terrestrial, atmosphere and climate, lithosphere and land, and oceans finally.
In the solar-terrestrial area, NOAA, jointly with DOD, provides forecast and warning services related to solar events. NOAA monitors such events using a combination of both space and terrestrial sensors. NOAA also participates in research to get a better understanding of the electric and magnetic fields and particle fluxes that surround the Earth. And finally, NOAA houses the World Data Center-A for global solar-terrestrial physics programs.
In the atmosphere and climate area, a similar array of NOAA programs are involved. They range from the day-to-day forecast activities of our National Weather Service, supported by our global satellite network, to research on global ocean circulation, and on to the so-called El Nino effect in the Pacific. And finally, we have, of course, the archiving of our climatic records at our Asheville, North Carolina, facility.
In the lithosphere and land area, NOAA's National Geodetic Survey is studying the motion of the Earth's poles and the motion of tectonic plates. NOAA maintains the World Data Center-A for solid earth geophysics and glaciology. In addition to operating the Landsat-4 and -5 satellites, which are a rich source of data concerning the lithosphere and land, NOAA also works with AID to assist developing countries in the use of satellite data and the management of drought situations. All of these things are relevant in a very direct way to the ultimate objectives of IGBP.
Finally, in the area of oceans, NOAA is again involved in the full range of activities ranging from services to the maritime community—which are a rich source of data on ocean parameters, ocean circulation, ocean waves—again relevant to IGBP. We are also involved in research on new techiques for ocean sensing and research on the ocean itself. And finally, of course, we are responsible for the archiving of civil oceanographic data.
In closing, I'd like to make one or two comments about the presentation of my colleague, Dr. Tilford. President Reagan, of course, has announced a major new initiative for NASA, the space station. One element of that proposal, the astronaut-tended polar platform,

has the potential to produce the most revolutionary Earth Observation System that man has ever conceived. Such a system will play a vital role in the IGBP, and we certainly are looking forward to working closely with NASA in its definition and development.

Sir, that completes my prepared statement.

[The prepared statement of Dr. McElroy follows:]

STATEMENT OF DR. JOHN H. MCELROY, ASSISTANT ADMINISTRATOR FOR ENVIRONMENTAL SATELLITE, DATA, AND INFORMATION SERVICES, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, U.S. DEPARTMENT OF COMMERCE

Mr. Chairman and Members of the Subcommittee:

I am pleased to be here today to testify on the subject of the proposed International Geosphere/Biosphere Program (IGBP).

The National Oceanic and Atmospheric Administration (NOAA) is actively involved in each of the scientific disciplines that are associated with the IGBP. Indeed, the scope of the proposed activities is not dissimilar to the research and service efforts that NOAA conducts. While NOAA does not have an identified program or office specifically devoted to IGBP, many of our scientists conduct research that would contribute directly to its objectives, and many of our information resources--whether satellites or data archives--will provide supporting and ancillary information that will be necessary to interpret the scientific results that would result from IGBP.

For over a decade NOAA has been engaged in research and monitoring of the Earth's oceans, atmosphere, and land masses

using space and ground-based systems. In the next few paragraphs, I will summarize selected NOAA programs that are relevant to the IGBP. For convenience, I will use major categories that are similar to those employed in the IGBP discussions:

- Solar-terrestrial
- Atmosphere and climate
- Lithosphere/land
- Oceans

Solar-Terrestrial

One of the major programs in NOAA relating to solar-terrestrial studies is the collection, archiving and dissemination of data from around the world. NOAA's Space Environment Laboratory provides real-time monitoring and forecasting services, develops techniques necessary for forecasting of solar-terrestrial disturbances and their subsequent effects on the near-Earth environment, and conducts research in solar-terrestrial physics in support of the service mission. Staffed jointly by the Air Force, the Laboratory carries out monitoring and forecasting services to meet a wide variety of civilian, military, commercial, and Federal agency requirements. The scope of the services ranges from the real-time collection of solar-terrestrial data to issuance of forecasts, alerts, and warnings of adverse solar-terrestrial phenomena, to the archiving and processing of solar-terrestrial data from all over the world, to the development of

an understanding of the behavior of the solar-terrestrial environment to yield significant service improvements. All of these service or service-related activities directly support the objectives of the IGBP.

Another NOAA element, the National Geophysical Data Center (NGDC) acts as the World Data Center-A (WDC-A) for global solar-terrestrial physics programs. NOAA participates in several working groups of the Scientific Committee on Solar-Terrestrial Physics (SCOSTEP). The Middle Atmosphere Program (MAP) Steering Committee guides a coordinated international program of data collection and analysis dealing with the chemistry and physical dynamics of the atmosphere from 10 to 100 km altitude. NGDC maintains a special data base of information collected in 1976-1979 for the International Magnetospheric Study (IMS). NOAA also participates on the Steering Committee for Monitoring the Sun-Earth Environment (MONSEE) for the collection, archiving, and distribution of data for magnetospheric physics, atmospheric physics, and solar-interplanetary physics.

The GOES and NOAA satellites carry an instrument called the Space Environment Monitor (SEM). This sensor measures the solar proton flux, electron flux density and energy spectrum, and total particulate energy distribution for monitoring sun spots and flares and their effects on the Earth's magnetic field.

Atmosphere and Climate

The National Climate Program Act of 1978 (P.L. 95-367) established a program intended to assist the Nation in understanding and responding to climate processes and their implications. Natural events as well as human activities affect climate in ways that may have profound social, economic, and political consequences. Recent events such as the El Nino, the eruptions of Mount St. Helens and El Chichon, and the major droughts that have affected many areas of the world all illustrate the sensitivity of the global system to natural phenomena. The continuing debates concerning global warming due to increasing atmospheric carbon dioxide or the impacts of acid rain further illustrate the need for careful, objective scientific analyses of these controversial, yet important, subjects. The National Climate Program Office is administratively located within NOAA, but has the coordinating role for all Federal activities in this area. Many of the activities coordinated by the Office are directly supportive of an IGBP, or would fall under its umbrella as an integral part. The Office coordinates the activities of the Departments of Agriculture, Commerce, Defense, Interior and State, the National Aeronautics and Space Administration, and the National Science Foundation.

The study of the Earth's atmosphere involves numerous programs conducted by NOAA. The National Environmental Satellite, Data, and Information Service (NESDIS) is currently monitoring the

stratosphere using satellite data to evaluate, develop, and implement specific systems for measuring the composition of this layer of the atmosphere. This program includes the establishment of a satellite-based operational ozone monitoring system. NOAA/NESDIS will participate as well in the International Satellite Cloud Climatology Program (ISCCP).

NOAA's satellite and ground-based stratospheric ozone programs are part of the World Meteorological Organization's Global Ozone Monitoring Network. This international program examines the impact of halocarbon emissions on the ozone layer, acquires information on the ozone's global variability and vertical distribution, and provides information to national and international agencies for the protection of the public health and welfare.

In 1979, the WMO established the World Climate Program (WCP). This program is designed to organize studies of climatic changes and their impacts on the natural environment and world food supply and to plan and execute an integrated international effort on climate change and variability. For its part, NOAA provides satellite and ground measurements to be used in ocean-atmospheric interaction studies; equatorial Pacific Ocean climate studies; studies on the long-term effects on man-induced and natural changes on the climate; and in determining the effect cloud cover has on the Earth's radiation balance.

The Global Environmental Monitoring System (GEMS) was organized in the early 1970's by UNEP. This project is an international effort to coordinate various activities used in monitoring the Earth, to acquire data needed for the rational management of the environment, and to track and assess environmental trends. In support of this program, NOAA provides a network for world monitoring of CO_2; a system for ozone monitoring; air quality and acid rain monitoring; snow cover assessment; ocean monitoring; and sea ice monitoring.

NOAA's National Weather Service (NWS) is actively involved in the WMO's global meteorological program--the World Weather Watch (WWW). The WWW is a global observing system that obtains and disseminates surface, marine, upper air, radar and satellite observations of the atmosphere and oceans to serve as the foundation for weather forecasts, storm warnings and environmental quality assessments worldwide. NOAA not only aggregates and disseminates global satellite and ground-based observations but also provides facilities for the World Meteorological Center in Washington, D.C.

Through a program of international data exchange, NESDIS aggregates and disseminates global ocean, atmosphere, solid earth and solar-terrestrial data and data products used worldwide in research concerning the physical environment and its interactive processes. Additionally, NESDIS, based on this aggregated data,

produces and disseminates global assessments of the impact of natural or human-caused environmental changes on food production, energy demand, water resources, health and welfare, and commerce.

Generally, NOAA is extensively involved in programs to understand the chemical and radiative interactions of the atmospheric trace species. To this end NOAA's technical programs include:

- Long-term monitoring on a global basis of CO_2, chlorofluorocarbons, ozone, water vapor, nitrogen trace species and aerosols.
- Measurements of the transport of trace species throughout the troposhere and stratosphere and the definition of these species in global photochemistry.
- Development of global and regional models of the atmosphere and oceans to project changes in concentration of trace species and their climatological consequences.

A major effort is planned to address the chemical and climatic role of trace species other than CO_2--most notably, methane and tropospheric ozone.

In addition to efforts under the World Climate Program, NOAA participates in several other international climate activities. Researchers have postulated that the most significant air-sea interactions affecting the climate occur in the tropics. As such, oceanographic research has focused on the equitorial Pacific and the El Nino phenomenon. Models are being developed for real-time

prognosis and prediction of regional climate perturbations during El Nino/Southern Oscillation (ENSO) episodes. Relevant NOAA research in this area is used in the Equitorial Pacific Ocean Climate Studies (EPOCS), the Tropical Ocean and the Global Atmosphere (TOGA) program, and the World Climate Research Program (WCRP).

Lithosphere/Land

The study of the Earth's land masses is one that involves numerous activities of a diverse nature. NOAA's National Geodetic Survey (NGS) is currently involved in a bilateral program with the Federal Republic of Germany called International Radio Interferometric Surveying (Project IRIS). The primary objective of this program is to improve the monitoring of polar motion and Earth rotation and measure changes between the North American and and European plates. Improved geodetic monitoring systems will contribute significantly to our understanding of the dynamics of the Earth's atmosphere, ocean, and land masses. Further geodetic studies are also being conducted using satellite data to monitor the Earth's crustal motion.

NOAA/NESDIS participates in the International Union of Geodesy and Geophysics (IUGG). Activities include the international collection of data and analyses for derivation of geophysical indices and acting as the World Data Center-A for Solid Earth Geophysics and Glaciology. Also, NOAA/NESDIS

participates in the Inter-Union Commission on the Lithosphere (ICL) to coordinate data management activities of the International Lithosphere Project (ILP).

NOAA is responsible for the operation of Landsats-4 and -5, and will be responsible for management of the Federal data purchase from the private sector if the system is transferred. NOAA will also be responsible for such minimal regulatory activities as will be necessary in the future for commercial land remote sensing systems, e.g., initial licensing. The existence of a commercial land remote sensing activity will ensure the continued availability of high-quality geological and other data that will directly support IGBP investigations.

Land and water resources are being monitored regularly on a worldwide basis using satellite and ground measurements. NOAA participates in UNESCO's International Hydrological Program (IHP) and the WMO's hydrology and water resources program. NOAA hydrologists provide hydrological data for world water resources management, the development of methods and techniques for water resources management, and an improved understanding of the interrelationship between human activities and the world's hydrological system.

Using satellite and conventional data, NOAA monitors regularly significant climate changes for agriculturally significant regions of the world. Data from the NOAA polar-orbiting

satellites are used to develop daily surface insolation estimates, precipitation estimates, and global vegetation index products. NOAA satellite data are also used to develop global snow cover and climatology maps and to measure and analyze the Earth radiation budget and global cloud cover.

In a related area, NOAA has been tasked by the Agency for International Development (AID) to assist countries in the developing world on drought impact assessment. These techniques and the data produced by these activities support the biosphere element of the IGBP. The AID-funded activities employ conventional and satellite data and are being pursued in Asia, Africa, and South America. The in-situ data and the detailed test cases that are a part of the drought assessment efforts will allow an evaluation to be made of the results stemming from the IGBP.

Oceans

In the area of ocean monitoring, NOAA's Marine Pollution Assessment Program provides scientific information that can be used to minimize the adverse consequences of marine waste disposal and accidental discharge of hazardous substances in our oceans. NOAA contributes these findings to various international organizations and studies. Through NOAA, the United States participates in the Global Investigation of Pollution in the Marine Environment (GIPME)--a program established by UNESCO's Intergovernmental Oceanographic Commission (IOC). GIPME provides a continuing assessment of the health of the oceans through regional programs

and the development of uniform analytic and data management methodologies. The primary focus of this program is to establish the relationship between marine pollution and its effect on ocean organisms and man. NOAA currently provides technical support for the program and facilities that serve as the regional management center for pollution data. Additionally, the National Ocean Service (NOS) is currently conducting long-term studies of sea-level variations for climate monitoring and coastal erosion research.

Another major effort in the IOC is the Integrated Global Ocean Services System (IGOSS). Not only does NOAA provide data for this system, but it also maintains a file of all IGOSS collected data for distribution. The National Oceanographic Data Center (NODC) collects and archives global ocean measurements and participates in the IOC's Marine Environmental Data and Information (MEDI) oceanographic data referral service.

Data from NOAA's polar-orbiting environmental satellites are utilized in examining various ocean-related phenomena worldwide. One such program measures and analyzes the distribution and concentration of aerosols over the oceans using data from the Advanced Very High Resolution Radiometer (AVHRR). Through its satellite program, NOAA also monitors worldwide sea surface temperature for studies of ocean currents, wave dynamics, and ocean upwelling. Sea surface temperature data are important in NOAA's research activities examining the relationship between

the ocean and atmospheric events. In the late 1980's, the United States will launch the Navy Remote Ocean Sensing Satellite (N-ROSS) and the European Space Agency (ESA) will launch ERS-1. Both satellites will provide global data on ocean dynamics. NOAA is discussing with ESA and the Navy cooperative arrangements for reception, processing, distribution, and archiving of data from these missions. Such data will play a vital role in understanding the Earth's oceans.

NOAA's National Marine Fisheries Service (NMFS) is conducting research on the distribution and abundance of contaminants in estuarine, coastal, and shelf waters. Data from these efforts are used to measure the biological effects of contaminants on living marine resources. NOAA's activities in this are coordinated with those of other nations through the Marine Environmental Quality Committee of the International Council for the Exploration of the Sea (ICES).

Data Management

A key element in the success of the IGBP will be the ability to manage the collection, processing, distribution, and archiving of a tremendous amount of data. NOAA, as the World Data Center-A for Meteorology, Oceanography, Solar-Terrestrial Physics, Solid-Earth Geophysics, Marine Geology and Geophysics, and Glaciology, has extensive experience in the coordination of space and ground-based observations.

Conclusion

The IGBP is a scientific program that examines the total Earth system as a single entity made up of many interconnected and interdependent elements. Those system elements include all of the disciplines that are represented in NOAA's research and service missions. The information resulting from NOAA's programs will be of vital importance to the successful conduct of the IGBP.

Mr. VOLKMER. Thank you very much, Dr. McElroy.

Dr. Trivelpiece.

Dr. TRIVELPIECE. Mr. Chairman and members of the committee, thank you for inviting the Department to testify on some of its activities.

I would like my prepared statement submitted for the record also, with your permission.

I'd like to begin by making an observation that virtually everything the Department of Energy does, or anything that involves energy, either comes from or goes back into the ground, the Earth, and virtually everything we do has some influence on—sometimes people worry about the influence—but on the atmosphere and the biosphere.

As a result, there are extensive programs that deal with what goes on in the ground in connection with nuclear weapons—the minerals that make up nuclear weapons come from mining that we have some involvement in—the health and safety of the individuals involved in these activities; the general burning of coal and what it does, the chemistry associated with that; the concern from the downwind plume that's associated with powerplants and various releases; are things that led to the Department having a program which, in aggregate, can easily be in excess of $100 million of things which would involve the IGBP activities. And probably when you take into account the contributions made by the development of the advanced computers that are used that were originally designed for the design of nuclear weapons—that these computers are the kinds of data management tools that will make possible the successful IGBP, and have found their way into the community generally.

So we have a strong involvement in this in the sense that we are a generator of the kind of data that will make a contribution to the IGBP, and we are also a user of information that is likely to be generated by it. So we strongly support it and are pleased to have this opportunity.

And I would like to take this occasion to read back to you some of your own material which is from your authorization report, 98-687. With your indulgence, I'd like to begin.

"The committee has examined DOE's programs, and has concluded that these have potential to make a major contribution to IGBP. It is crucial to draw upon the strengths of the academic community in formulating the U.S. role in this program. Resources spent by DOE in these areas will achieve a substantially greater value if coordinated with an overall observation and research effort. The committee urges DOE to cooperate with other agencies to support IGBP in defining its scope and objectives and in developing future plans." Couldn't have said it better.

Thank you, Mr. Chairman. I'd be glad to answer any questions.

[The prepared statement of Dr. Trivelpiece follows:]

STATEMENT OF DR. ALVIN W. TRIVELPIECE, DIRECTOR, OFFICE OF ENERGY RESEARCH, DEPARTMENT OF ENERGY

Mr. Chairman and Members of the Subcommittee:

It is a pleasure to appear before you today to describe the Department's involvement with the proposed International Geosphere/Biosphere Program (IGBP).

The Department of Energy supports the concept of an IGBP - a study of whole systems of interdisciplinary science in an effort to understand global changes in the terrestrial environment and its living systems.

The Department has recently provided $30,000 for partial support of the National Academy of Sciences' Committee for the International Geosphere/Biosphere Program. This committee will explore the possible scope and benefits of an IGBP. We are particularly interested in the committee's plan to address questions of whether links between areas of study are strong enough to justify an IGBP and whether the formation of a new program will significantly complement important ongoing and proposed programs. We look forward to the report of this committee.

Following the NAS committee study, the Department will be most interested to review the IGBP plan to consider how we may contribute. As pointed out by the National Academy Workshop report (NAS, 1983), in implementing an IGBP, careful attention must be paid to all relevant national and international programs already conceived and in various stages of progress. Proper planning should guarantee that these programs are carried forward effectively and that an IGBP complements these programs.

The Department has several such programs which we feel can make valuable contributions to an IGBP and in turn may themselves benefit from the existence of an IGBP.

The Carbon Dioxide Research Program, which is a national research program with the Department serving as lead agency, was organized in 1978 to identify possible policy options for governmental action in response to any carbon dioxide-induced changes in climate, agriculture and other human endeavors. The

achievement of this goal requires a significant increase in our scientific knowledge of the atmosphere, the biosphere, the oceans and the cryosphere - their interactions and the effects that increasing atmospheric CO_2 and other trace gases will have on them. This was listed as one of the key global and multidisciplinary problems by the NAS workshop.

The geosciences research program of our Office of Basic Energy Sciences supports research aimed at developing a fundamental understanding of the physical mechanisms responsible for various solar-atmospheric-terrestrial interactions. One of the primary objectives here is to develop a predictive capability in solar-terrestrial research (for example, the predictable effects relating the behavior of the sun and the earth's magnetosphere and magnetospheric processes to terrestrial weather and climate). The mathematical and computer science capabilities of the DOE laboratories make it possible for DOE to contribute significantly, especially in the area of modeling.

The marine research program supported by the Department's Office of Health and Environmental Research is focused to provide scientific information on questions surrounding two major environmental issues facing development and expansion of most energy technologies - waste disposal and siting/operations. An integrated, multidisciplinary program is being conducted which combines research on transport and fate of contaminants with studies on water mass movements and ecosystem structure and function. This type of effort is also related to an IGBP.

Finally, the Department's Office of Health and Environmental Research atmospheric sciences program should be mentioned. Its objective is to develop an understanding of the chemical, physical and meteorological processes which determine the characteristics and fate of energy related emissions. The program provides the tools required to make assessments of

the impact of future energy-siting and fuel-use strategies on local and regional air quality. It also provides atmospheric pollutant input data for study of ecological and human health effects. Conceptually, the program is an integration of individual modules of transport and dispersion meteorology, atmospheric chemistry, aerosol physics, removal processes and resuspension of surface particles.

In summary, the Department supports the concept and goals of the International Geosphere/Biosphere Program and looks forward to determining how we can contribute to and gain from an IGBP.

Mr. Chairman, this concludes my prepared statement. I would be happy to answer any questions at this time.

Mr. VOLKMER. Thank you very much, Dr. Trivelpiece.

Dr. Bridgewater, we have a vote to approve the Journal. If you can complete your testimony within, I'd say, 7 minutes, we'll start with that.

Dr. BRIDGEWATER. Thanks. I can take much less than that.

Mr. VOLKMER. All right.

Dr. BRIDGEWATER. Thank you, Mr. Chairman, for the opportunity to testify today on behalf of the National Science Foundation. There are several points which are made in my prepared statement, which I would like to have submitted for the record.

Mr. VOLKMER. All of your statements will be made a part of the record at the point of your testimony.

Dr. BRIDGEWATER. Their key point is that the Foundation supports the concept of the IGBP. My directorate, in particular, all along has had an active involvement in major international and interagency activities of this sort, so it's nothing unusual for us, and we expect to be a full participant in the development of an IGBP.

There is concern at this point that there is not a clear concensus in the academic community as to the nature of the IGBP or the involvement of academic scientists, and that is something that we hope will be clarified at the ICSU Symposium in September and subsequent discussions of the Academy and the other participants in the development of the IGBP.

We, of course, as an agency that supports research, in response to proposals that we receive from the community, are very much dependent upon the community involvement. We can assist, to some extent, in encouraging that community involvement by supporting the planning activities, and we are prepared to do so, but we are, of course, dependent upon proposals that come in-house. As of this point, we have not seen the proposals that are responsive to the IGBP objectives, but we would expect that, over the next two

years as the concept becomes more developed and more mature, we would see the proposals and that the Foundation will respond appropriately.

That is really the substance of our testimony.

[The prepared statement of Dr. Bridgewater follows:]

STATEMENT OF DR. ALBERT L. BRIDGEWATER, ACTING ASSISTANT DIRECTOR FOR ASTRONOMICAL, ATMOSPHERIC, EARTH AND OCEAN SCIENCES, NATIONAL SCIENCE FOUNDATION

Good afternoon, Mr. Chairman. I am pleased to have the opportunity to testify before the Subcommittee on Space Science and Applications on behalf of the National Science Foundation regarding the proposed International Geosphere-Biosphere Program (IGBP). In your letter to the National Science Foundation, Mr. Chairman, you asked us to address two specific questions. I will address these questions in order and then conclude with some general comments.

The first question was, "What has NSF done with respect to the Committee's request that NSF support the IGBP ?" The National Science Foundation has responded positively to the Committee's urging that we "cooperate with other agencies to support the IGBP in defining its scope and objectives and in developing future plans"[1] NSF participated in the 1983 National Research Council Workshop at Woods Hole which resulted in the first statement of U.S. objectives for an IGBP.[2]

Similarly we participated in the Summer Study on the IGBP which the National Academy of Sciences (NAS) convened at Woods Hole in June of this year to develop a more detailed statement of IGBP objectives and to identify sound scientific approaches to achieving these objectives.

NSF has indicated to the National Aeronautics and Space Administration that we would be willing to share in Federal interagency support of NAS planning activities related to the IGBP. Two NSF staff scientists - a meteorologist and an oceanographer - will attend the special Symposium on the IGBP being planned

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1 House Report 98-642, "Authorizing Appropriations to the National Science Foundation", Section II.17, Committee Views on Programs and Policies: NSF Role in the IGBP.

2 "Towards an International Geosphere-Biosphere Program", National Academy Press, 1983.

by the International Council of Scientific Unions (ICSU) on September 25 in Ottawa.

It was our understanding that the recent NAS summer study was intended to produce a draft report which then would be distributed for review by summer study participants late this summer, before being put in a form that could serve as a basis for informal discussions at the ICSU Symposium later this month. However, the summer study did not produce a draft report. We now understand that a small drafting group met in Massachusetts last week to complete this task. This represents a significant delay. More importantly, this series of actions suggests that there is not yet a clear or present consensus in the U.S. scientific community as to the objectives of an IGBP or the scientific approaches that should be followed to achieve those objectives.

The second question that you addressed to us in your letter was, "How will the IGBP help NSF to accomplish its primary mission?" As you know, NSF's mission is to support basic research - the best and most promising basic research that U.S. scientists and institutions propose to us. Large multi-institutional international programs can advance high-quality research in many ways. They can encourage scientists and institutions to attack problems of vast scope and scientific significance. They can facilitate interaction and communications among scientists on a regional or even a global scale. Thirdly, they can serve as a catalyst for governments and agencies which support science to provide necessary scientific, technical and financial resources. The IGBP has encouraged some outstanding scientists from the United States and other countries to discuss and to outline initial objectives for an IGBP. The IGBP has served as a catalyst for many of these scientists to meet later this month in Ottawa to further discuss these objectives under the sponsorship of ICSU.

The key question for the National Science Foundation is whether the IGBP will encourage first-rate U.S. scientists to prepare first-rate proposals to NSF for study of first-rate scientific problems.

The National Science Foundation presently supports and is actively working with academic research scientists in planning for U.S. scientists to participate in another major global research program - the World Climate Research Program (WCRP). It may be useful to note how this program developed. This program is being sponsored jointly by the World Meteorological Organization (WMO) and the International Council of Scientific Unions (ICSU).

The WCRP traces its roots to the successful Global Atmospheric Research Program (GARP). The results of GARP convinced many scientists in the U.S. and other countries that international research and technological capabilities would permit, in the late 1980's and 1990's, comprehensive studies of the global atmosphere and ocean that could provide a basis for later development of predictive capabilities for global climate.

A series of scientific workshops, both international and within the U.S., led to the planning of at least three new major international research programs in conjunction with the WCRP: the international satellite cloud climatology program (ISCCP); the study of the interannual variability of the tropical ocean and the global atmosphere (TOGA); and the world ocean circulation experiment (WOCE).

Outstanding U.S. scientists and engineers have been involved both in development of the above programs and in planning of the U.S. components of these three programs. These scientists and institutions have worked closely together to develop exciting first-rate scientific proposals for future research in these areas. As a result, at least three Federal Agencies - NASA, NOAA and NSF - have become involved in the WCRP. These Agencies are working closely with each other and with research scientists to finalize scientific planning for these programs.

It is not yet clear to us, Mr. Chairman, whether an IGBP offers the same potential for NSF to support exciting first-rate research. Thus far, IGBP planning in the area of biogeochemical cycles seems to be the most advanced and to offer the most exciting scientific challenges. Research into interaction among the atmosphere, ocean, cryosphere and biosphere also may be able to build upon and extend the value of the climate research we already have embarked upon. It is not yet clear whether other research topics identified in early IGBP documentation will offer similar opportunities for cohesive and effectively integrated global research programs. The ICSU Symposium later this month, and the final report of the recent NAS summer study on the IGBP, may help to answer this question. If it does, Mr. Chairman, then an IGBP may be able to make a contribution to improving our understanding of the interaction between man and the planet he inhabits.

We are prepared, of course, to continue to work with the scientific community and with other interested Federal Agencies to provide full opportunities for planning an IGBP. The National Science Foundation would be very pleased to receive proposals from the U.S. scientific community for exciting basic research associated with an IGBP.

Thank you, Mr. Chairman. I am now prepared to answer any questions.

Mr. VOLKMER. Thank you very much.

We still have a little time. I will recognize the gentleman from New Mexico for any questions he may have.

Mr. LUJAN. Thank you, Mr. Chairman. That's such a gigantic program and everything that it's difficult to try to formulate any questions. There are a couple of things that I wonder about. One, of course, is budgetary, and can the agencies handle it. And second——

Mr. VOLKMER. Would you yield to the gentleman from California?

Mr. LUJAN. Sure. Strike that. I'll yield to the gentleman from California, Mr. Brown.

Mr. BROWN. Well, I appreciate the gentleman's courtesy very much.

I wanted to comment briefly with regard to the emphasis that I think a couple of you gentleman have placed upon the information aspects of this program. I personally feel, and I commented on this yesterday, that this could be the most important contribution that—that a massive international research program of this sort could contribute—that is, the better management of the global data

that is produced and make it available for the use of scientists throughout the world.

My question is, do you think we can achieve that kind of benefit from this program if we give it sanction as a major program?

Which one of you made the—was it you, Dr. McElroy that—or was it Dr. Tilford?

Dr. TILFORD. Either one. Go ahead, John.

Dr. MCELROY. Let me start off—and I am sure that Dr. Tilford will have other comments as well—we believe that the data management problem is quite possibly the most significant challenge in IGBP. For that reason, we've been very pleased that Dr. Malone has offered the opportunity for my Deputy Assistant Administrator for Information Services, Margaret Courain, to participate fully in the definition activities. And she is working on, for example, the CODATA Committee to address precisely those issues.

In all of our centers for climatic data, for geophysical data, for oceanographic data, all of these are challenges which--we are facing challenges which are quite similar to IGBP and will have to be expanded rather remarkably in their—not in their resources so much—but in their approach to handling this flow of data.

Dr. TILFORD. I would concur with John. I think, without doubt, even considering the hardware and science interpretation and putting together a realistic data system for the 1990's, is probably the most challenging problem we have.

I think that's one thing we have tried to do with the upcoming future satellite programs, is include an integrated data as part of that. We're learning very much as we go along. I think we have to be careful that we don't develop a system that's not going to be useful to the users.

Mr. BROWN. All right.

I think the other members of the committee will want to explore in more specific terms just what action would be most helpful at this time, but I don't want to bring that up at this point because of the time problem. But, obviously, the committee is supportive, as indicated in our reports, but we don't want to embark on premature or—or overly-ambitious efforts, and we need advice and guidance as to how we can contribute to the continuation of the work that's being done already in this program.

Thank you, Mr. Chairman.

Mr. VOLKMER. Thank you.

Do you want to have—do you want finish up any more?

Mr. LUJAN. Let's go and come back.

Mr. VOLKMER. All right. The committee will now recess, and we will return at approximately 25 after 10—11.

[Recess.]

Mr. VOLKMER. The subcommittee will come back to order.

I'd like to proceed with some questions. Yesterday during the testimony, it was brought out the International Geophysical Year, the IGY, of 1957-58 could possibly be a model for the IGBP. I'd like to first know which of your agencies participated in the IGY? Let me start with Dr. Tilford.

Dr. TILFORD. Through the satellite program, NASA was a very active participant. Of course, in IGY, I think many of the observing programs were tied around the Explorers that were launched in

that timeframe. Of course, that was just the beginning of the space program. I think many respects of IGY, of course, in terms of international scientific cooperation, do apply to IGBP.

On the other hand, I see IGBP as being much broader on the one hand and much more focused on the other. So I think certain things, in terms of IGY, would apply. However, I do see IGBP being much more complicated in the sense that I do see it being more focused, and especially with respect to the ground observations in terms of the biosphere. So I think it is a partial model, but I think you have to look to other things like GARP as perhaps being better models for this international program.

Mr. VOLKMER. All right.

Then what about the—being able to have a data system to be able to handle all the data that we're going to have if we do have the IGBP?

Dr. TILFORD. I think it's feasible that we can develop in the next 5 or 10 years a data system that will handle much of the data. With technology today, in terms of optical disks, et cetera, we do have the capability for archiving and retrieving great volumes of data.

I think what we have to learn to do is not only just archive the data, but be able to utilize data and use it in a systematic fashion. I think that will take much more time and be much more difficult. We could completely be inundated by data bits and not get very much information out of it. I think we have to be very careful that does not happen.

Mr. VOLKMER. Dr. McElroy, in regard to IGY.

Dr. MCELROY. Yes, sir. The predecessor organization to NOAA, the Environmental Science Services Administration, was indeed involved, both from the satellite perspective, as well as from the—from large ground-based or terrestrial experiments.

Certainly the—the analogy is—is good to an extent. I think there's one ingredient which isn't often mentioned, and that is that IGY was—in addition to being a program, was a frame of mind. I think IGBP is similar in that respect. You don't necessarily have to have a—a program office to have an effect from IGBP, because once the scientists start thinking of this earth systems model, begin to approach it from that perspective, there are certain things which just fall into place that are supportive of IGBP without it ever becoming formal.

Mr. VOLKMER. OK.

Dr. Trivelpiece, did the DOE participate in IGY?

Mr. TRIVELPIECE. DOE has only been in existence about——

Mr. VOLKMER. It didn't exist, but any of the——

Dr. TRIVELPIECE. Its predecessor agency, the Atomic Energy Commission, I suspect was involved in it. But I really, from personal knowledge, am not—am not aware of anything. I'd be glad to try to explore that and provide it for the record, if you wish.

[The information follows:]

International Geophysical Year (IGY) was a vast scientific enterprise conducted from July 1, 1957 to December 31, 1958 involving scientists from 67 nations. International programs were carried out in the following subjects: "World Days" and communications, meteorology, geomagnetism, aurora and airglow, ionosphere, solar activity, cosmic rays, longitude and latitude, glaciology, oceanography, rockets and sat-

ellites, seismology, gravity measurements, and nuclear radiation. The IGY programs were organized by academies and international unions of scientists through nongovernmental channels. Individual governments provided most of the money, but each paid only for its own national programs. Information is not readily available on the AEC's specific contributions to these subject areas; however, we were able to ascertain that AEC was involved in the Nuclear Radiation Program in which the atmospheric transport of radioactive materials was studied.

Mr. VOLKMER. RIGHT.

Dr. TRIVELPIECE. I would like to support what Dr. McElroy said, and that is that it is a frame of mind, and the idea that people simultaneously throughout the world begin to look at a particular kind of scientific research for a particular purpose provides a cooperative beneficial effect. That is what this is more about than a particular program within the United States. The word "international" really needs to be emphasized. And I think these kinds of programs produce ancillary benefits in terms of scientific cooperation and collaboration, and of causing people who did not otherwise and might not otherwise come together to come together and engage in cooperative programs. There's quite a bit of ancillary benefits that result from them.

Mr. VOLKMER. All right.

Dr. Bridgewater.

Dr. BRIDGEWATER. Yes, the Foundation did actually participate in IGY, and many of the programs in my directorate really have their genesis in the IGY.

Shelby mentioned the Global Atmospheric Research Program as a better example of the kind of activity that might be supported under the IGBP program activities. The Foundation manages the Global Atmospheric Research Program. It's in its phase-out period, but we're still doing analysis of the data that was collected during the field experiments.

Mr. VOLKMER. All right.

In regard to the—the international program, yesterday we also discussed whether or not we're going to need a strong national program before we get into an international program. Do you—any of you disagree or agree with that?

Dr. TILFORD. I think we all strongly agree with that. As was stated yesterday, I believe that, without having a strong national program, there is no possibility of developing a strong international program.

Dr. MCELROY. Yes, sir.

Mr. VOLKMER. You all agree on that?

Dr. TRIVELPIECE. Everybody has to bring something to the table in the event of an arrangement.

Mr. VOLKMER. Right.

In that regard, Dr. Bridgewater, I'd like to ask if there's—the attitude of the NSF will be one of waiting for proposals to come in and seeing what proposals do come in, as far as the biosphere or geosphere, or whether you'd take a more active role in attempting to solicit such type of proposals?

Dr. BRIDGEWATER. We frequently find that we have the chicken-and-the-egg phenomenon. It's sometimes hard to determine whether the proposals come first or whether the NSF staff involvement comes in first in terms of stimulating the proposal. I think that we

will be active in terms of encouraging the planning process, but we cannot send any money out the door without a proposal.

Mr. VOLKMER. I agree on that, but you can take steps that would let know that such proposals would at least be considered, is that correct?

Dr. BRIDGEWATER. And we do take those steps quite frequently.

Mr. VOLKMER. So that you're not going to just sit back, necessarily, and wait for some proposals to come in?

Dr. BRIDGEWATER. We have not done so so far.

Mr. VOLKMER. All right. Thank you very much.

We already have—I think I already know the answer to the question, but for the record, various global international research programs, global climate, global environmental monitoring systems and the others, why the need for an IGBP? What can it offer that the other ones cannot or do not?

Dr. TILFORD. I think the unique contribution, at least at this particular stage in the formulation of IGBP, is the inclusion of the biosphere. Most of the other worldwide programs now have to do with physical phenomena, weather climate, et cetera. I don't believe any of these programs have taken into consideration the biogeochemical cycles as being an integral part. I think this is the one thing which ties the whole system—the earth together, and that's the biology. I think this is the first effort to look on a global scale of biogeochemical processes.

Mr. VOLKMER. All right. Anyone else wish to comment?

Dr. TRIVELPIECE. Such things as pollutants don't seem to know or recognize international boundaries, and the degree to which cooperation can be obtained in that kind of information exchange and cooperative research, I think everyone benefits, and I would second the issue on biology.

Mr. MCELROY. Sir, I would like to add to that one current issue which always faces us is our precise knowledge of the way the system behaves. We often hear reference to the Global 2000 reports. Some people speak favorably about it, some people speak unfavorably about it. There has been recently published a Global 2000 Revised report, which takes quite a different perspective.

The advantage of a program like IGBP is that it offers the opportunity to make an objective analysis of—of what actually is happening, and not to take inadequate data and try to make what may be a political judgment as to what that data means. So it is a more objective perspective.

Mr. VOLKMER. Has the National Climate Program been a success?

Dr. MCELROY. I believe it has been, sir. Certainly it is a—a small-scale activity. It is, of course, housed within—in NOAA, but with an interagency set of responsibilities. Dr. Alan Hecht has recently generated an annual report describing some of those achievements, and perhaps the most effective thing to do would be to provide you with a copy of that as it is available.

Dr. TILFORD. I guess that I would like to comment. I have a little different perspective, I think, in terms of defining success for a program. I think, certainly in some aspects, the program has been a success. On the other hand, I don't believe it has achieved what it has set out to do in the establishment of the National Climate Pro-

gram Office with a National Climate Program Act. I would have liked to have seen it be a lot more aggressive.

Mr. VOLKMER. In that light, then, as far as maybe showing the feeling of the Congress in regard to the IGBP, testimony yesterday was that—Dr. Malone—that, at the proper time, a nonbinding, but at least concurrent, resolution by the House and Senate would be an enormous value. Would that be true along the line of what you are now saying? Or would you even want to go further than that?

Dr. TILFORD. I think it would be beneficial. I could envision a binding statement perhaps being a lot more beneficial——

Mr. VOLKMER. Right.

Dr. TILFORD [continuing]. In terms of implementing a program.

Dr. MCELROY. Indeed.

Mr. VOLKMER. I have no further questions.

Does the gentleman from New Mexico have any questions?

Mr. LUJAN. Thank you, Mr. Chairman.

As I tried to say before I yielded to the gentleman from California, who had to leave, it's a gigantic program, as I see it, to gather all that information. And I want to visit a little bit perhaps about logistics and those sorts of things.

It is my understanding that—first of all, that it's to be done—all of this is to be done within existing budgets; is that correct? Is that the way you foresee it?

Dr. TILFORD. That's—that's not the way I interpret it, sir.

Dr. MCELROY. Certainly in the NOAA context, that's certainly the case.

Mr. LUJAN. But I suppose, you know, that there's some research program or something that you consider, like a new start or something like that. Generally, it's the kind of work that you're not doing.

How do you think that——

Dr. TILFORD. Well, I certainly think that a very large portion of the program is covered now under the existing budgets. But as I stated before, I do think that a long-time series of a number of data sets are required in order to implement IGBP.

In many cases, we have certain elements of those data sets; in many cases, we do not. I do not see how to implement such programs without additional resources in future years.

Mr. LUJAN. Where do we begin with this thing. There's a lot of information out there already. You were discussing the weather things, and Dr. Trivelpiece was talking about the, you know, when you mine in the ground and the coal and all of those things. Is there any kind of a coordinated effort now where all of this is put together? And I assume that this whole program leads to—you know, we're going to have this mountain of information, all concise, for everybody to see the reaction when you stick the shovel in the ground, what's going to happen on the moon or in the ocean or something. Is there—yes, Doctor.

Dr. TRIVELPIECE. Not that I'm aware. But the kind of thing that I think is beneficial that can happen as a result of this is pick, for example, the concern over acid rain. As I said earlier, it doesn't know national or international boundaries. And if simultaneously a collection of scientists from several countries agree to perform more or less the same measurements at the same time with the ob-

jective of understanding this over a larger geographic region, then there is a benefit. If, simultaneous to that, a collection of people who are interested in doing weather modeling or providing information, and meteorologists are taking information and recording data, so that there's simultaneity of interest across a large collection of areas in which you can observe correlations that might otherwise escape notice—and it is this idea of doing it all at one time, in one interval, to make a concerted effort to make sure that the data is available to everyone.

Otherwise, people—scientists are already doing these kinds of studies and, in many cases, there are local correlation effects. But this extends the correlation distance and time in a way, I think, that benefits everyone, even though it does produce a kind of data glut and there is some need to manage the data, and there's also a need to ignore some of the data. And that, I think, is one of the challenges that some of the next generation of scientists that are involved in these areas are going to have to face up to, as to how to ignore about 50 percent of the data.

Mr. LUJAN. And once you do that simultaneous monitoring or research or whatever, where's it going to end up, in the files of the National Science Foundation or over at NASA or DOE?

Dr. TRIVELPIECE. I think it should remain in the hands of scientists who are doing the work, that the object is to coordinate it in such a way so that the information, the detailed information, gets passed to those individuals who are doing it. Some archiving will need to be done, and I presume that the various agencies that are involved could have their agents provide the storage and archiving for that data that was of interest to them.

Dr. TILFORD. I think that we have to really look strongly toward providing improved capability in the total data handling system beyond what we've done in the past. I agree with statements made earlier that this is the most complex area. And I don't see a large centralized data base, but I do see a number of distributed data bases with connecting facilities and communications such that people can have access to them, which has not been the case in many examples that we had in the past.

Mr. LUJAN. What are we looking about—at, some agency leading this effort, or are we just saying——

Dr. TILFORD. Well——

Mr. LUJAN [continuing]. You continue to do your thing, or DOE or——

Dr. TILFORD. Frequently, my perspective is that, when you assign a lead agency, you don't necessarily achieve the objectives. I would look to the scientific community to provide the internal leadership and focus with agency participation on a national basis, and subsequently on an international basis, because I think——

Mr. LUJAN. What do you mean, put together a board or a steering committee?

Dr. TILFORD. Something along that line, yes. And I think we have to look to the international organization ICSU to provide the international scientific leadership. Otherwise, I believe politics will prevent the program from being anywhere near a success.

Mr. LUJAN. Well, it certainly is a gigantic undertaking. The only—when you were talking about how far up we're going and

how far down we're going, we had a constituent that had a claim for the mineral rights for a quarter section up in the north country of our State. The Government was maintaining that he didn't have the mineral rights to it, that the Government had retained those. But as we looked for his papers, we found that it was a grant to his grandfather or great grandfather from the King of Spain originally, and the wording was that his rights were from the heights of heaven to the depths of hell. And I thought that guy's got a pretty good claim on the mineral rights, which, as a matter of fact, we finally did, you know, we gave him the deed to the mineral rights.

But that is kind of as far we have to go, from the heights of heaven to the depths of hell, to see how this whole world is sticking together.

Mr. BYERLY. We ought to get NOAA to work on that.

Mr. LUJAN. Huh?

Mr. BYERLY. We ought to get NOAA to define that.

Mr. LUJAN. There you go. That's it. Rad says we ought to have NOAA define that for us.

Thank you very much, Mr. Chairman.

Mr. VOLKMER. I have a couple additional questions.

Dr. Tilford, at the bottom of page 3 of your statement, you use the words, "I should add that, to the best of our knowledge, there has been no viable relationship proposed between the Sun and our weather that could be tested in a definitive manner."

What exactly do you mean by that?

Mr. TILFORD. Well, I think we have to be very careful here to define Sun-weather and Sun-climate relationships. I'm talking cause-and-effect relationships on a 2-day to 2- to 3-week time period. We certainly know that the Sun has immense influence on the climatic conditions over seasonal periods—it gets cold, it gets hot in the northern hemisphere and the southern hemisphere, et cetera.

However, we have found no coupling mechanism, as Dr. Bretherton indicated yesterday, which essentially transitions the upper region, the solar winds, et cetera, except some very minor perturbations during very severe solar storms. Today, we simply do not have a coupling mechanism between solar output, in terms of sunspots, et cetera, such that we do not know of any viable mechanisms to couple short-term variations in the Sun or solar wind with weather as we observe it on the ground. It's a cause-and-effect relationship.

We don't—there's been a number of hypotheses to propose such statistical variability. We have not found any coupling mechanism that can be definitively identified.

Mr. VOLKMER. Be able to give a test—in other words, the short-term effect of any of the solar—or sun's movements or movements——

Mr. TILFORD. On a short timeframe, I believe this is correct. Although if you listen to certain weathermen within the Washington area, they claim to be able to do that.

Mr. VOLKMER. All right. But in other words, that is an area in which we will have to improve our ability and technology?

Dr. TILFORD. Well, I think we need to, again, establish long-term data sets in order to understand the cause-and-effect relationship.

The El Nino effect described yesterday is another example. We don't know whether it's initiated by the atmosphere or whether it's initiated by the ocean. We do know that, once it's initiated, we can predict the kind of effects we will observe, and sometimes the duration of them. The causal effects have not been defined, and that's simply, I believe, primarily because we don't have sufficient data bases to look at this in detail.

Mr. VOLKMER. All right.

Mr. LUJAN. That's like the red sky at night, sailor's delight, and all of that, isn't it?

Dr. TILFORD. Yeah. If you put volcanoes in, that complicates it a whole lot.

Mr. Lujan. Dr. McElroy, before I ask you that question, and I want to—because basically it has to do with parts of your statement also. Do you have any comment you wish to make on the last answer by Dr. Tilford?

Dr. MCELROY. I concur completely with his answers, sir.

Mr. VOLKMER. That gets me to your statement then, where you get into, "The scope of the services ranges from the real-time collection of solar-terrestrial data to issuance of forecasts, alerts, and warnings of adverse solar-terrestrial phenomena, to the archiving and processing of solar-terrestrial data . . ." Now what's solar-terrestrial data? What are we talking about there?

Dr. MCELROY. Solar-terrestrial data includes all of the influence of the particles in electric and magnetic fields which radiate out from the Sun during severe events and then propagate out through the solar system. And as they enter the environment of the Earth, they disturb such things as the ionosphere; impacting long-range radio communication; they impact upon long pieces of metal, for example, oil pipelines and things of this sort, long transmission lines. And as they do so, they induce into those metal objects very large electric currents which often disrupt operations. So there are a number of quite mundane, but very serious, implications of events which occur some 93 millions away.

In addition to that, when our colleagues in NASA have astronauts outside of the space shuttle, they are concerned always about the radiation environment that those astronauts are subject to. So we maintain a constant watch of the—of the sun to alert those astronauts about any possible danger.

Mr. VOLKMER. OK.

And then you say, "All of these services or service-related activities directly support the objectives of the IGBP."

Dr. MCELROY. Yes, sir.

If I——

Mr. VOLKMER. Can you give me a specific example of that?

Dr. MCELROY. Yes, sir.

If you look at the IGBP, there is—there are disciplined data bases which are required to understand the coupling among those various disciplines. For example, if you are—are worried about this system as a total entity, then you have to know what input you're having under normal circumstances, what input you're having under perturbed circumstances, and how they might be translated then from one, say, the biosphere to the atmosphere, from the atmosphere to the ocean, and so forth. So you need all of your basic

discipline data bases and understanding if you're going to put this total picture together.

Now because we have all of those data archives, they will be certainly a valuable source of input to the program.

Mr. VOLKMER. All right.

Approximately how often on an annual basis would the, say, perturbation of the sun that causes the problem, the magnetic problems, et cetera, occur?

Dr. MCELROY. I can't give you any statistics on that. That's way outside my discipline.

Mr. VOLKMER. All right. I was just curious. I was just curious.

Dr. TILFORD. It varies very, very much, depending on the "solar cycle." At the peak of the 11-year sunspot cycle, there's perturbations at least on a weekly basis. During quiet times, you may go with several months without major perturbations.

Mr. VOLKMER. All right.

Mr. LUJAN. I don't either.

Mr. VOLKMER. Do you have anything else?

I want to thank all four of you. And I'm sorry we were not able to start on time. We did have a Caucus this morning.

We will keep the record open for any answers to questions. There may be some written questions that may have to be submitted, and we will ask for your written reply as soon as possible so we get those. And we will hold the record open for that and for any additional material.

I appreciate your being here. You've been very helpful. Perhaps we can see the beginning of the IGBP as an idea starting out, and it may be in fruition a few years from now. So thank you very much.

[Whereupon, at 11:55 a.m., the subcommittee was adjourned.]

APPENDIX

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September 4, 1984

Hon. Harold L. Volkmer
Chairman
Subcommittee on Space Science and Applications
Committee on Science and Technology
U.S. House of Representatives
Suite 2321, Rayburn Office Building
Washington, D.C. 20515

Dear Mr. Volkmer:

I am writing in anticipation of the scheduled hearings by the Subcommittee on Space Science and Applications regarding a proposed International Geosphere/Biosphere Program.

Following the publication of the report of a 1982 NASA-sponsored Woods Hole conference, Global Change: Impacts on Habitability, Columbia University made a serious commitment to the NASA global habitability concept. In September of 1983 we established a University Seminar on Global Habitability, which brings together at monthly meetings an interdisciplinary group of scientists from the academic community, from federal research agencies (AID, DOE, EPA, CEQ, NAS, NASA, NOAA, OJCS, DOS, USDA, USGS), the Congress, world Bank, United Nations, and foundations and other private institutions.

The seminars focus on those global changes that have resulted from the intervention of man on the environment, and they encourage research among disciplines to further the exchange of critical data.

It is important to note the impressive commitment of these scientists, whether from the public or private sectors, to an interdisciplinary program of research directed to these issues. I recently talked with agency personnel about initiation of a training program to provide interdisciplinary learning experiences in federal Laboratories for post-doctoral scientists from developing countries. There was uniform enthusiasm, and evidence of cooperation and dedication to improving the ability of scientists worldwide to reverse the trends that threaten the environment of our planet.

We are pleased to express our support of this extremely worthwhile program.

Sincerely yours,

Ruth Levenson
Associate Provost for Special Projects

cc: Hon. Manuel Lujon, Jr.
Hon. James H. Scheuer
Hon. Richard L. Ottinger
Hon. Paul Simon
Hon. Robert G. Toricelli
Hon. Claudine Schneider

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CENTER FOR THE STUDY OF GLOBAL HABITABILITY

Seminar on Global Habitability

September 14

"Observations of the Earth from Space"

Hon. Dr. Hans Mark
Deputy Administrator
National Aeronautics and Space Administration

Respondents: Dr. Herbert Friedman
National Research Council
National Academy of Sciences

Dr. Peter Thacher
Distinguished Fellow
World Resources Institute

Prof. Michael McElroy
Division of Applied Sciences
Harvard University

October 12

"Greenhouse Gases and Climate"

Prof. Wallace Broecker
Lamont-Doherty Geological Observatory
Columbia University

Respondents: Dr. John Hoffman
Director, Strategic Studies Staff
Environmental Protection Agency

Dr. James Hansen
Head, Goddard Institute for Space Studies

Dr. Richard Goody
Division of Applied Sciences
Harvard University

November 9

"Tropical Deforestation"

Dr. Norman Myers
Consultant in Environment and Development
London, England

Respondents: Dr. David Campbell
Research Fellow
New York Botanical Garden

Dr. Berrien Moore
Complex System Research Center
University of New Hampshire

December 14 — "World Food and Agriculture: Improving Global Habitability"

Dr. Patrick O'Brien
Deputy Director of Economic Research Service
U.S. Department of Agriculture

Respondents: Dr. Nyle C. Brady
Senior Assistant Administrator for
Science and Technology
Agency for International Development

Prof. David Pimentel
Department of Entymology and Agricultural Science
Cornell University

Dr. Peter Thacher
Distinguished Fellow
World Resources Institute

February 15 — "Acid Rain: Controversies and Current Understanding"

Dr. Gene Likens
Director, Institute of Ecosystem Studies
The New York Botanical Garden, Cary Arboretum

Respondents: Dr. Michael Oppenheimer
Senior Scientist
Environmental Defense Fund

Dr. Joseph Smagorinsky
Director, Emeritus
Geophysical Fluid Dynamics Laboratory
Princeton University

March 14 — "Population Trends and the Future Quality of Human Life"

Prof. Ansley J. Coale
Office of Population Research
Princeton University

Respondents: Dr. Bruce Shearer
President, Population Resource Center

Dr. Robert C. Repetto
Senior Associate
World Resources Institute

Dr. Steven Sinding
Director, Office of Population Programs
Agency for International Development

April 11

"The Future of the Antarctic Ice Sheet"

Prof. George Denton
Department of Geological Sciences
and Institute for Quaternary Studies
University of Maine, Orono

Respondents: Dr. Ian Whillans
Assoc. Professor, Department of
Geology & Mineralogy
The Ohio State University

Dr. George Kukla
Senior Research Scientist
Lamont-Doherty Geological Observatory
Columbia University

Dr. Robert H. Thomas
Manager of Polar Oceans Program
Ocean Processes Branch
NASA

May 29

"Energy Sources and Requirements"

Dr. Alvin W. Trivelpiece
Director, Office of Energy Research
U.S. Department of Energy

Respondents: Dr. Joel Darmstadter
Director, Center for Energy Policy Research
Resources for the Future

Dr. Roger Revelle
Director and Professor, Emeritus
Scripps Oceanographic Institute

Topics for the 1984-1985 Series:

"El Nino: Predictability of Oceans and Atmosphere"

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Geophysical Fluid Dynamics Laboratory
Princeton

Dr. Eugene Rasmusson
NOAA

Respondents: Dr. Mark Cane
Lamont-Doherty Geological Observatory

"Poverty and the Global Environment"

Eric Eckholm

"Consequences of Genetic Engineering"

Dr. Joshua Lederberg

"Chlorofluorocarbons"

Dr. Ralph Cicerone
Dr. Michael McElroy

"What is Happening to the European Forests and Why"

Dr. Bernhard Ulrich

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